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PRELIMINARY ANALYSES OF THE WASTEWATER AND ASSIMILATION CAPACITIES OF THE ANACOSTIA TIDAL RIVER SYSTEM

Norbert A. Jaworski, et al

Federal Water Quality Administration
Annapolis, Maryland

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Chesapeake Technical Support Laboratory
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Federal Water Quality Administration
U. S. Department of the Interior

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* Federal Water Quality Administration, Washington, D. C.

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CHAPTER I

INTRODUCTION

To provide information to assist in decision making as requested by Assistant Secretary of the Interior Carl Klein, a study of wastewater assimilation and transport capabilities of the tidal portion of the Anacostia River was initiated by the Chesapeake Technical Support Laboratory (CTSL) during April of 1970. This study was designed to investigate the effects of a wastewater discharge into the Anacostia River at or near the site of the abandoned Washington Suburban Sanitary Commission (WSSC) Plant near Bladensburg, Maryland. Currently, wastewater flows from the Anacostia Valley are conveyed to the Blue Plains Treatment Plant of the District of Columbia.

The Blue Plains plant is presently overloaded and plans are currently being developed to expand the facility. If this plant is to accomodate the projected wastewater volumes using current renovation processes, more land will be required for expansion. Other alternatives could be process changes that would allow increased volumes to receive required treatment within the same area or development of facilities to treat the wastewater at other locations such as the Anacostia Valley.

The major emphasis of this study was to determine the effect of a wastewater discharge on the water quality in the tidal portion of the Anacostia in the vicinity of the D. C.-Maryland Line (See Figure I).

Presented in this report are: (1) an assessment of the current water quality conditions, (2) a hydrologic analysis, and (3) preliminary results of the assimilation and transport capacities of the Anacostia tidal system.

UPPER POTOMAC AND ANACOSTIA
TIDAL RIVER SYSTEM

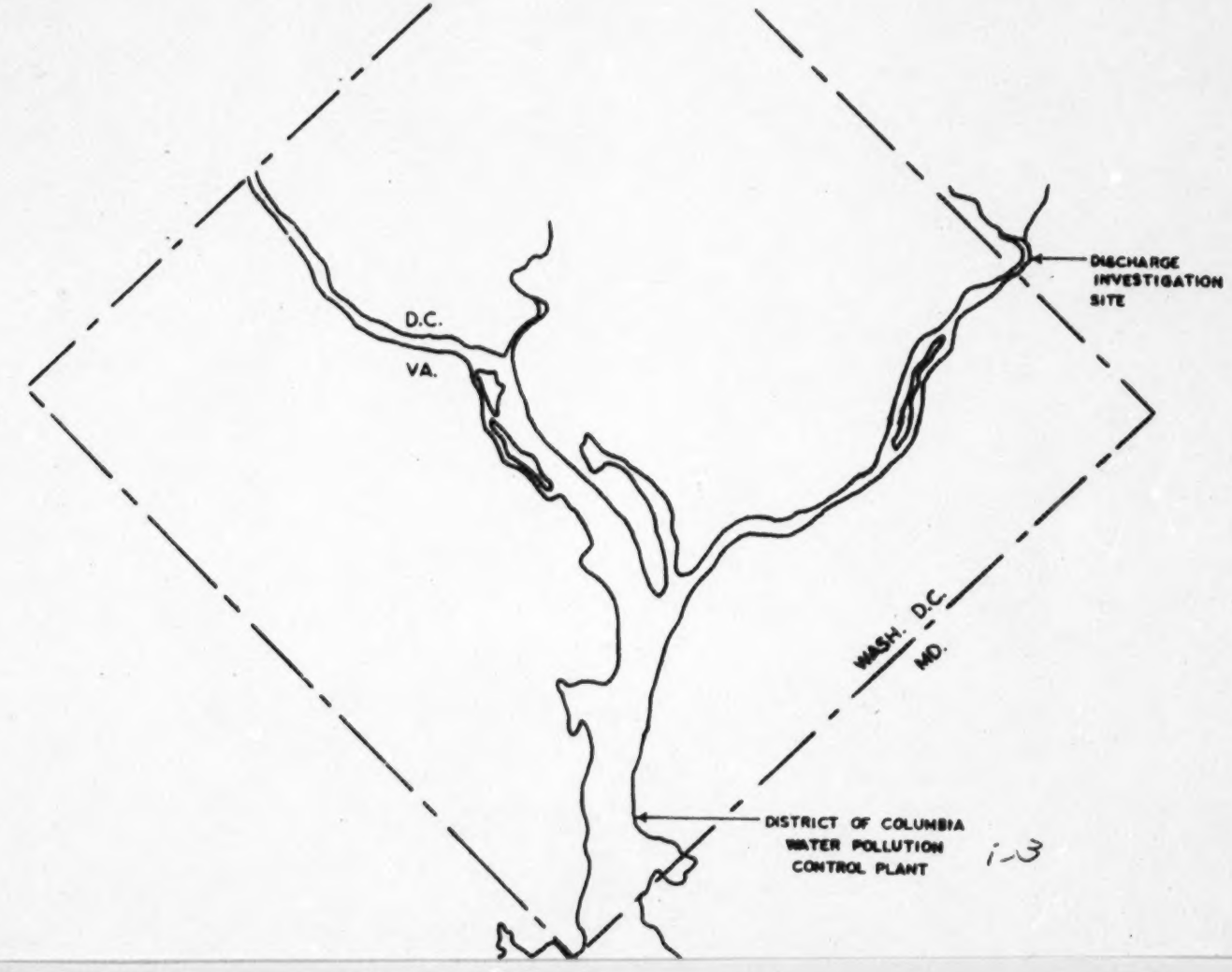


Figure 1

CHAPTER II

SUMMARY AND CONCLUSIONS

A preliminary analysis of the wastewater assimilation and transport capacities of the tidal portion of the Anacostia River has been made. The findings of this report, which are limited to predicting the possible effect on water quality in the Anacostia tidal river system of discharging treated wastewater from a service area comprising the Anacostia Valley in Maryland, are summarized below.

1. The Anacostia watershed, tributary to the Potomac Estuary near Washington, D. C., has a drainage area of 184 square miles, 30 square miles within the District of Columbia and 154 square miles within the State of Maryland.

2. The mean stream flow in the basin is about 122 cfs and the 7-day low flow with a recurrence interval of once-in-ten-years is 8 cfs.

3. The lower portion of the Anacostia River is a tidal freshwater system having a mean volume of about 540,000,000 cubic feet.

4. Based on 1969 sampling data, the water quality conditions in the tidal river under summer conditions are typified by:

   a. Low dissolved oxygen concentrations often falling below 2.0 mg/l,

   b. High fecal coliform densities often above 10,000 MPN/100 ml,

   c. High turbidity levels especially during periods of high runoff, and

d. High nutrient concentrations.

While some of the above water quality indicators which fall below accepted stream standards can be attributed to urban runoff, the most pronounced degradation results from storm sewer and combined sewer overflows and defective sanitary sewer systems.

5. The projected populations and wastewater flows of the water quality renovation facility investigated, at a site above the D.C.-Md. border and serving the Anacostia Valley in Maryland, are given below:

Year	Population	Wastewater Flows (mgd)
1970	466,000	55
1980	661,000	78
2000	744,000	88
2020	837,000	99

6. A comparison of the projected wastewater flows to the Blue Plains Treatment Plant of the District of Columbia excluding Anacostia flows and the flows from the Anacostia Valley is shown below:

Year	Blue Plains (mgd)	Anacostia Valley (mgd)	% of Blue Plains Flow (mgd)
1970	177	55	31
1980	231	78	34
2000	331	88	27

7. The ratio of projected Anacostia wastewater flows to the designated low stream flow criterion of 8 cfs, as presented below, vividly shows that most of the advective flow in the tidal system would be from the wastewater renovation facility.

Year	Stream Flow (cfs)	Wastewater Flow (mgd)	Ratio of Wastewater/Stream Flow
1980	8	78	15.1
2000	8	88	17.0
2020	8	99	19.2

8. Mathematical model investigations of the Anacostia River indicate that wastewater assimilation and transport capabilities for large advective flows are most sensitive to the decay rate of a pollutant and not to the dispersion effect of the tidal system. The sensitivity of the decay rate is a result of the long detention time of the tidal system while the effect of the dispersion coefficient is diminished by the pronounced advective movement.

9. Based on mathematical model studies and analysis of 1969 water quality data, it was concluded that the tidal system capability to assimilate oxygen demanding wastewater is currently being exceeded and that any wastewater discharged would have to be of better quality than that currently existing in the Anacostia.

10. The discharge of low turbidity effluents into the highly turbid Anacostia is expected to create nuisance algal blooms due to increased light penetration. Therefore, a high degree of nutrient removal will also be required.

11. Incorporating the need for enhancing the dissolved oxygen levels, preventing nuisance algal growth, and considering the large flow of wastewater compared to stream flow, effluent standards were used to determine wastewater renovation requirements. Renovation requirements for a discharge into the Anacostia are presented below:

Parameter	Before Treatment (mg/l)	Effluent Criteria (mg/l)	Percent Removal Range
BOD_5	200.0	2.0 - 4.0	98 - 99
T. Phosphorus as P	11.0	0.1 - 0.2	98 - 99
T. Nitrogen as N	22.0	0.5 - 1.0	96 - 98

12. An important requirement of the renovation process is an aerated effluent. Since most of the net advective flow will be wastewater, the effluent must have as a minimum 4.0 mg/l of dissolved oxygen to meet the DO standard in the Anacostia at the discharge site.

13. If the wastewater were subjected to high carbonaceous and nitrogenous BOD removal and if the effluent is aerated to 6.0 mg/l, the present water quality of the Anacostia River would be enhanced. The additional 2.0 mg/l in the effluent is expected to raise the DO to meet the standard of 4.0 mg/l at the critical point downstream.

14. The greatest uncertainty, even at high removal requirements, is the algal growth potential. The effluent, which would be the result of ultimate wastewater treatment (UWT) and would be considered suitable for many water uses, might still contain nutrients at concentrations capable of producing excessive algal blooms.

15. A dye tracer study was conducted in late April 1970, during preparation of this report, to ascertain tidal dispersion characteristics and residence times in the Anacostia tidal system. Other continuing studies will involve (1) water quality interactions between Kingman Lake and the Anacostia River, and (2) reaeration rates and benthic oxygen demands along the Anacostia. Results of these studies will be reported in progress statements of the Potomac Washington Metropolitan Area Enforcement Conference.

CHAPTER III

DESCRIPTION OF THE STUDY AREA

A. GENERAL

The Anacostia watershed, tributary to the Potomac River, lies within Montgomery and Prince Georges Counties in Maryland and the District of Columbia. The drainage area of the basin is 184 square miles and presently contains a population of approximately 993,000.

The tidal portion of the river extends from the Potomac River near Hains Point to the confluence of the Northeast and Northwest Branches, a distance of 8.75 miles. The mean volume of the tidal portion of the Anacostia is approximately 540,000,000 cubic feet. The nontidal portion of the watershed has a drainage area of 125 square miles. The 1967 population of the nontidal area was approximately 466,000.

The river mile locations of pertinent land features of the tidal system are presented below:

Item	River Mile
Hains Point	0.00
Douglas Bridge	1.45
11th and 12th Street Bridge	2.45
Sousa Bridge	3.10
Lower End of Kingman Lake	3.80
East Capitol Street Bridge	4.35
Benning Road Bridge	4.90
Upper End of Kingman Lake	5.65
U. S. Route 50 Bridge	6.90
WSSC Marina	8.10
Bladensburg Road Bridge	8.45
Confluence of Northeast and Northwest Branches	8.75

B. STREAM FLOW ANALYSIS

The nontidal stream flow of the Anacostia River comes primarily from the Northeast and Northwest Branches. Mean monthly flows of the two branches and their totals are presented in Table I.

Table I

Mean Monthly River Discharge

Month	Northeast Br. (cfs)	Northwest Br. (cfs)	Total (cfs)
January	89.6	51.6	141.2
February	110.4	64.1	174.5
March	128.0	73.4	201.4
April	108.2	64.1	172.3
May	78.6	50.9	129.5
June	57.5	39.7	97.2
July	48.1	32.6	80.7
August	66.4	40.8	107.2
September	42.6	28.1	70.7
October	44.5	24.8	69.3
November	63.4	38.0	101.4
December	75.3	43.0	118.3

The average daily discharge of the combined branches is 122 cfs with a 7-day low-flow recurring once-in-ten-years of 8 cfs. While the average flow is 122 cfs, the median flow (that flow occurring 50 percent of the time) is 66 cfs, indicating that stream discharge is flashy.

C. WATER QUALITY CONDITIONS

The water quality condition of the tidal portion of the Anacostia is monitored by the Department of Sanitary Engineering, District of Columbia and by the Chesapeake Technical Support Laboratory, Federal Water Quality Administration. Special studies of the entire basin were conducted by CTSL in 1967 and 1969.

The major sources of water quality degradation are land runoff, storm drainage, defective sanitary sewers, and combined sewers. There are no significant discharges from wastewater treatment facilities in the basin.

1. Dissolved Oxygen and Biochemical Oxygen Demand

The dissolved oxygen (DO) concentration in 1969 was depressed below 5.0 mg/l in most of the tidal system during most of July, August, and September. As can be seen in Figure II, the lowest concentration, between 1.0 and 2.0 mg/l, occurred in a reach near the Pennsylvania Avenue Bridge. A slight recovery occurred near the confluence with the Potomac.

The biochemical oxygen demand (BOD) of the tidal system ranged from approximately 2.0 to 7.0 mg/l (See Figure III). The concentrations were slightly higher near the D.C.-Md. Line, especially during high runoff periods.

Data from a special two-day survey made within the boundaries of Kingman Lake in June 1969 also show dissolved oxygen concentrations below 2.0 mg/l (See Appendix C). High BOD concentrations were also measured during that survey.

The water quality standard for DO for this reach of the Anacostia is a minimum of 3.0 mg/l with an average of 4.0 mg/l. This standard was not met in July, August, and September of 1969 in the tidal portion of the Anacostia. June 1969 surveys indicated the same to be true for the Kingman Lake area and the Pennsylvania Avenue sampling point.

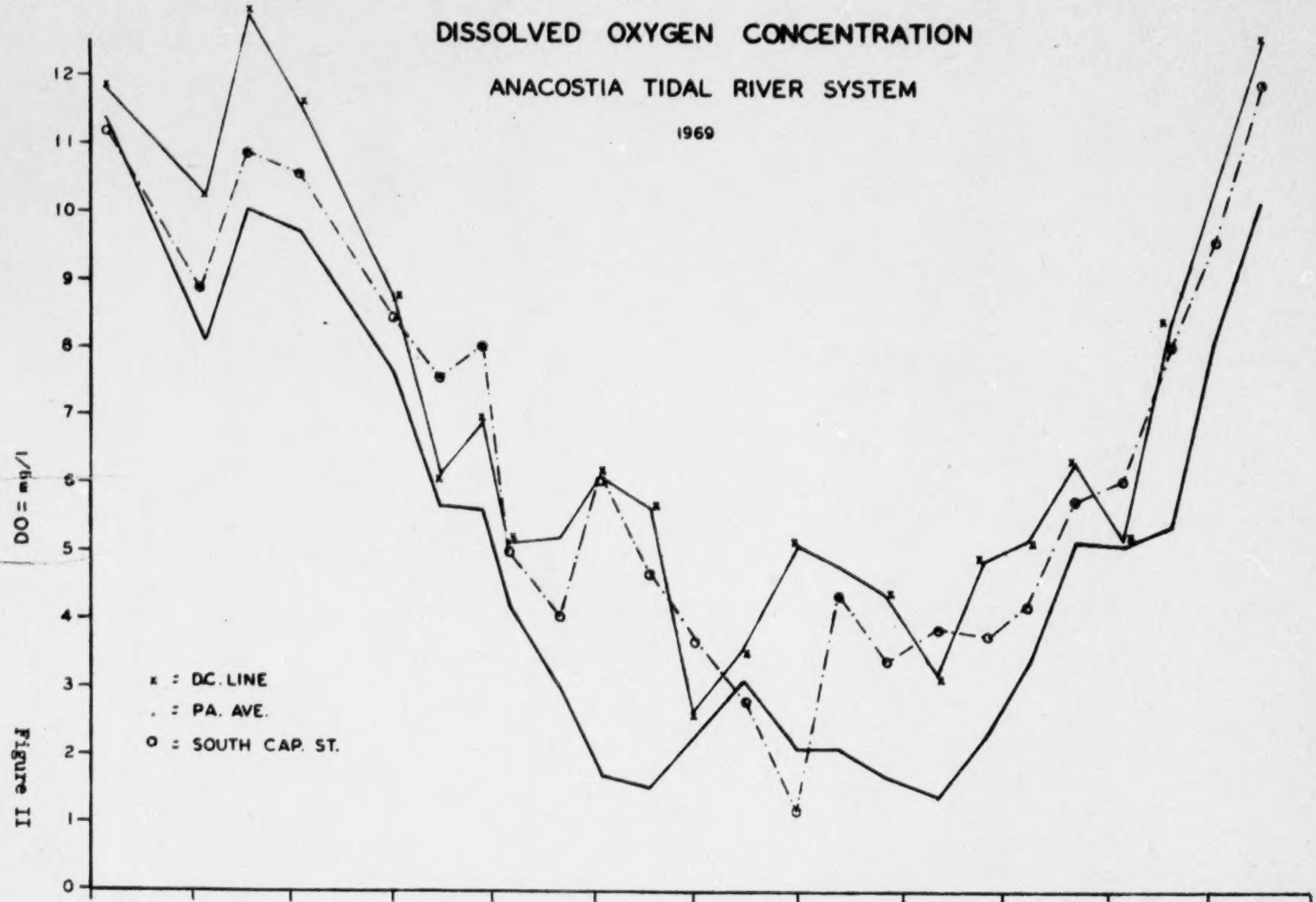


Figure II

III-5

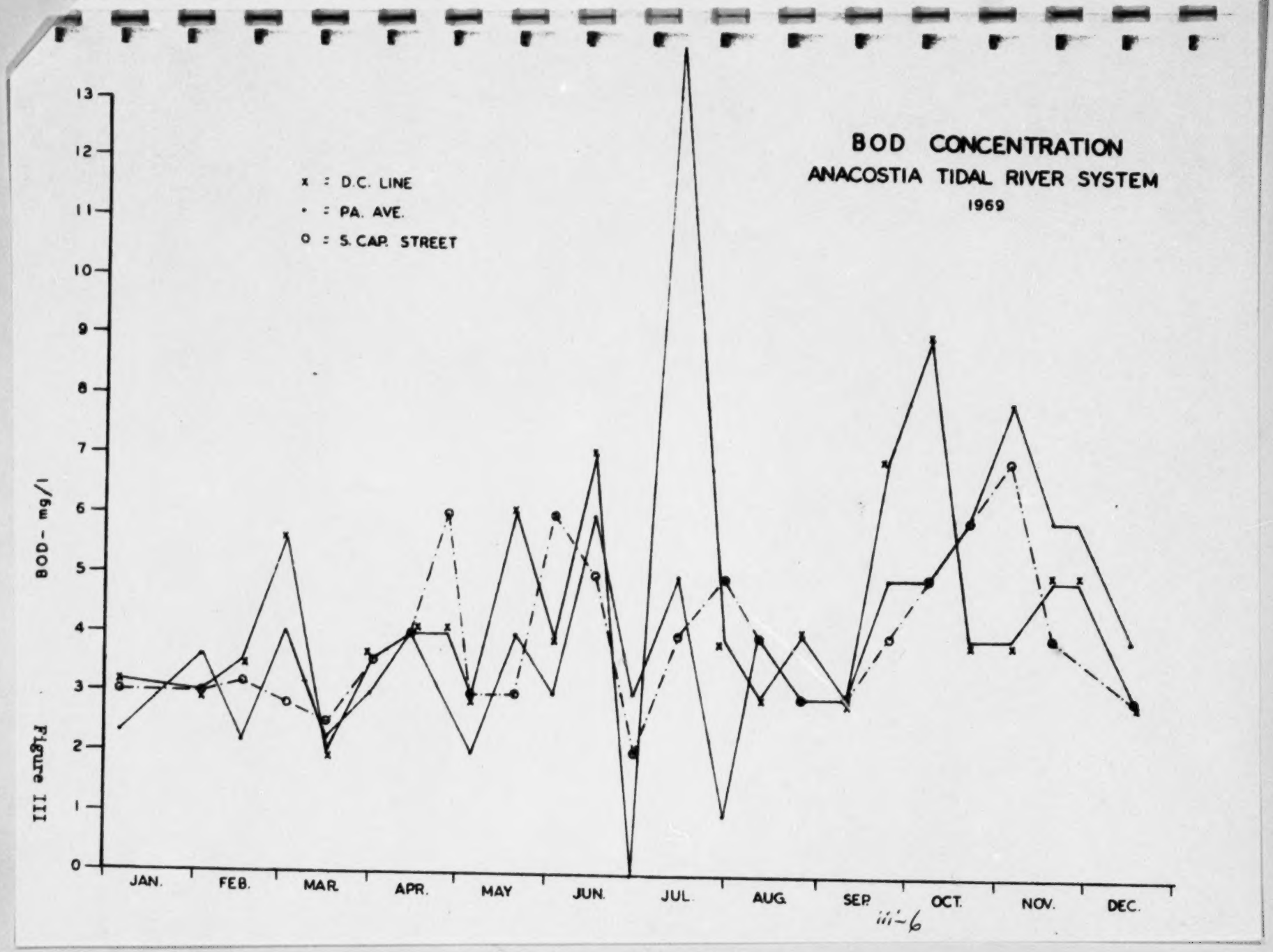


Figure III

III-6

2. Bacteriological Densities

Figures IV, V, and VI present the fecal coliform densities for the water quality sampling stations at the D.C.-Md. Line, Pennsylvania Avenue, and South Capitol Street Bridge. The data obtained by the District of Columbia Department of Sanitary Engineering indicate that fecal densities are higher near the D.C.-Md. Line. Densities over 10,000 MPN per 100 ml were measured frequently at the D.C.-Md. Line during 1969.

Data for the Kingman Lake study also indicate high fecal densities with counts ranging from 2,100 to 93,000. The fecal coliform standards, which are a geometric mean of 1000/100 ml and 10 percent of samples not to equal or exceed 2000/100 ml, are not currently being met in the tidal portion.

During the survey of the entire watershed in 1967, the Sligo Creek station at Chillum Manor and the Northwest Branch at Queens Chapel Road had the highest bacterial densities. Of the fifteen stations sampled, none had consistently higher densities than were found at the stations located in the tidal portion of the basin during 1969 (See Appendix A). This indicates that the high densities in the tidal portion are from local sources such as the sewer systems and not runoff originating in the upper drainage area.

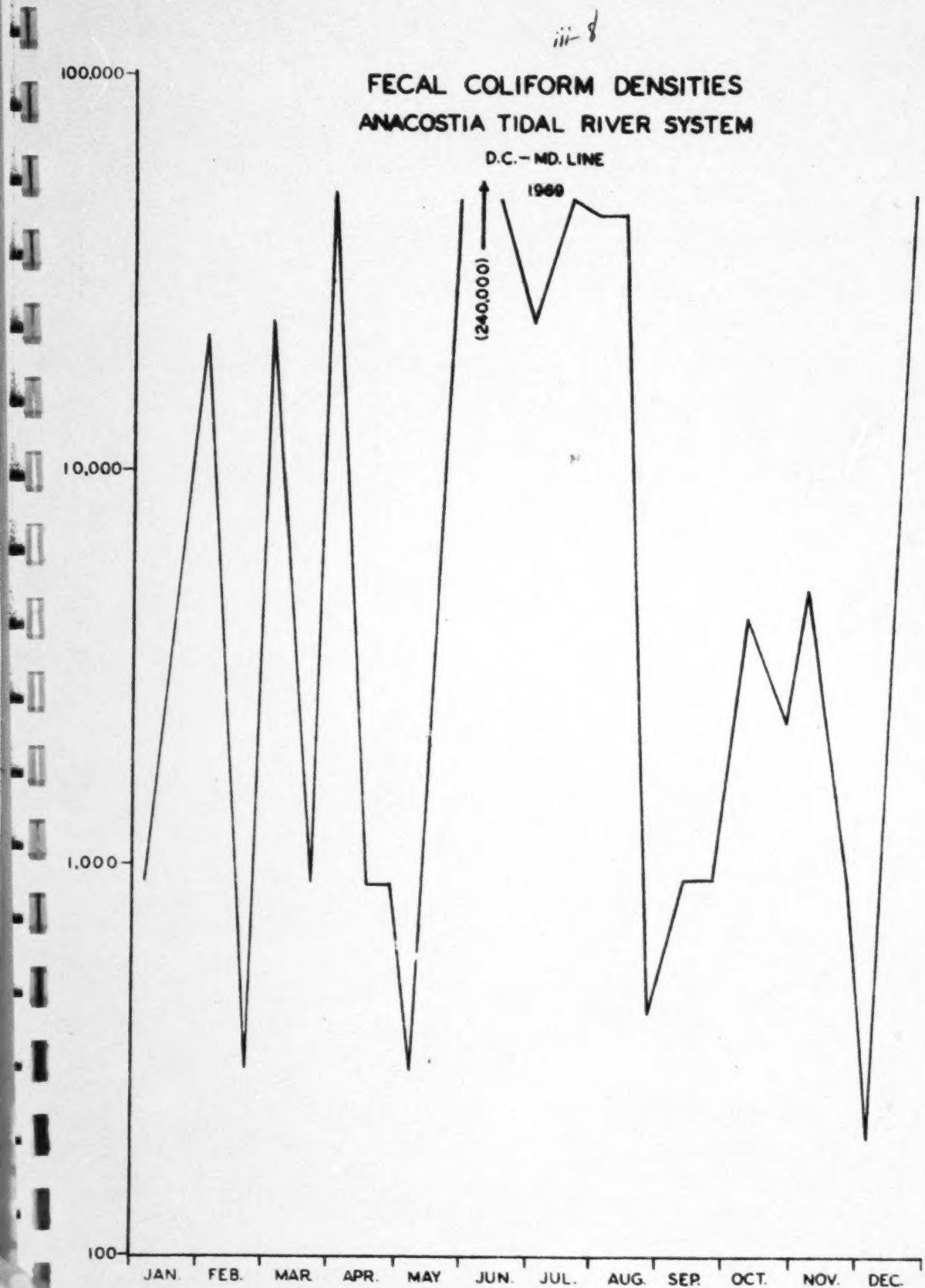

FECAL COLIFORM DENSITIES
ANACOSTIA TIDAL RIVER SYSTEM
D.C. – MD. LINE
1968
(240,000)
100,000
10,000
1,000
100
JAN.
FEB.
MAR.
APR.
MAY
JUN.
JUL.
AUG.
SEP.
OCT.
NOV.
DEC.

Figure IV

FECAL COLIFORM DENSITIES
ANACOSTIA TIDAL RIVER SYSTEM

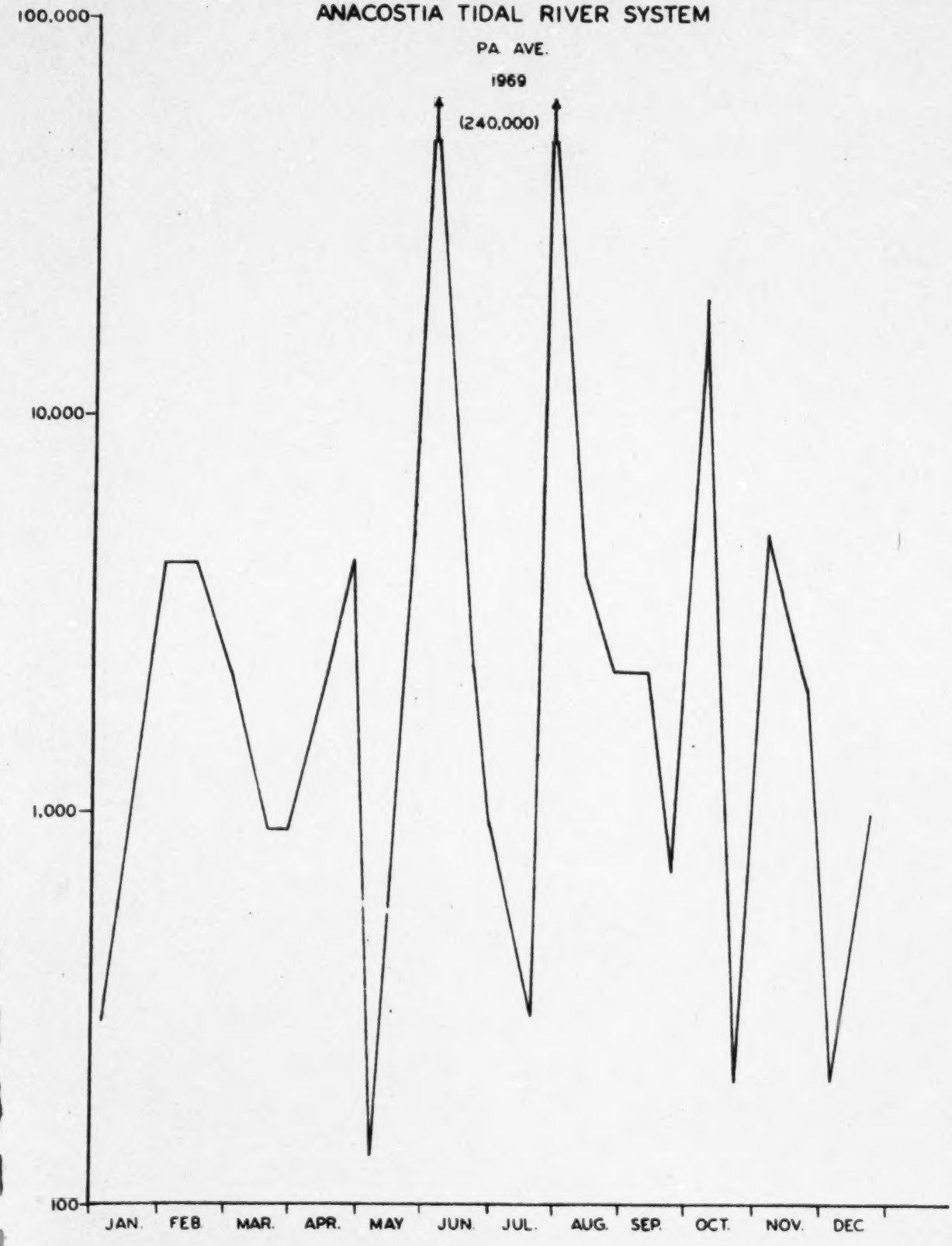


Figure V

FECAL COLIFORM DENSITIES

ANACOSTIA TIDAL RIVER SYSTEM

S. CAP. STREET

1969

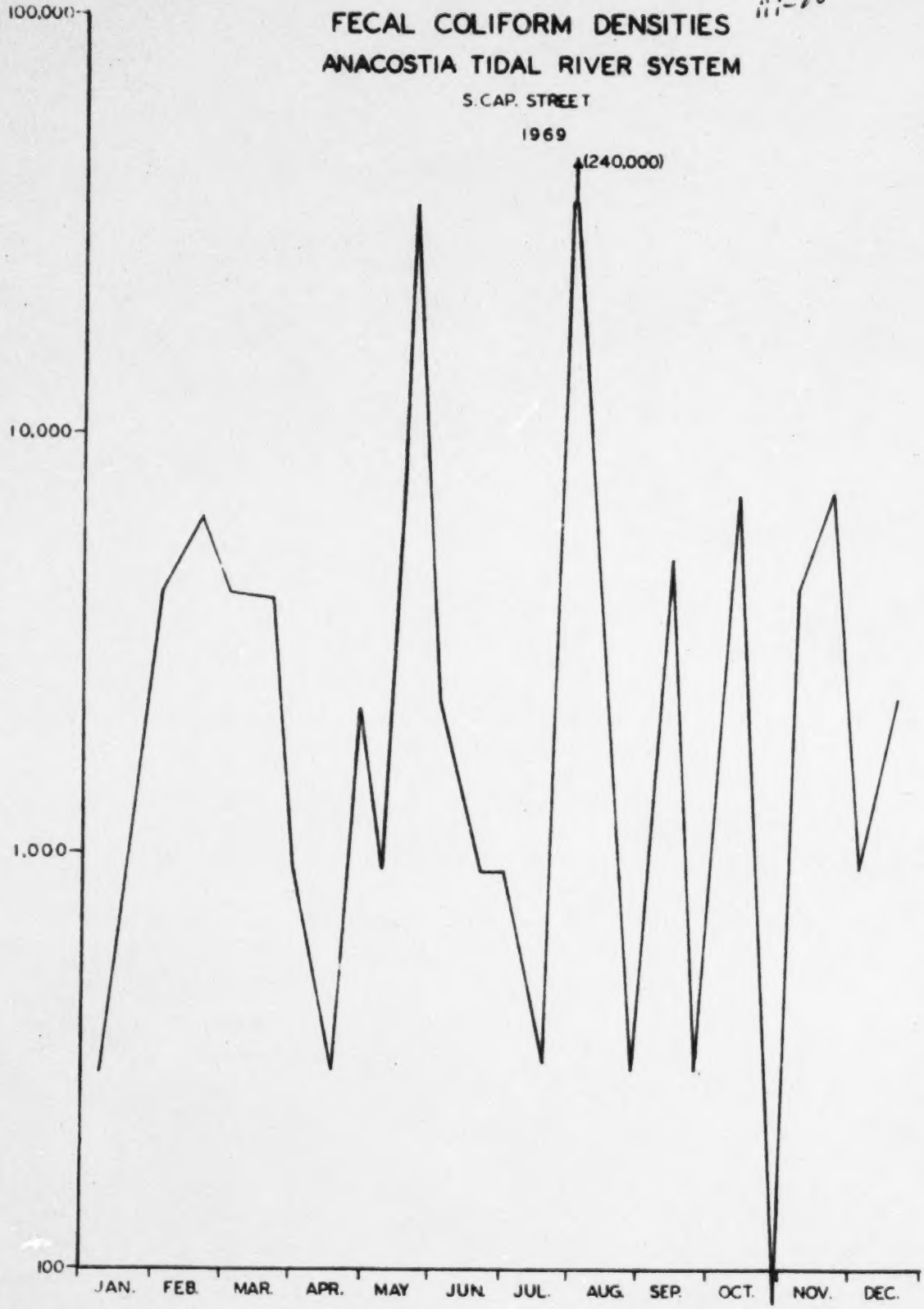


Figure VI

3. Nutrients

During the 1966 nutrient survey of the Potomac River Basin, phosphorus and nitrogen concentration data were obtained by CTSL, FWQA (See Appendix B). For 1966, the mean monthly nutrient concentrations and their loadings are summarized in Table II.

As presented in Table II, the average concentrations of phosphorus as PO_4, NO_3 as N, and TKN as N were 0.80, 0.86, and 1.24 mg/l for the Bladensburg station during 1966. The resulting loadings for the stations in 1966 were 374, 513, and 633 lbs/day of phosphorus as PO_4, NO_3 and TKN, respectively.

Phosphorus concentrations as high as 8.7 mg/l as PO_4 have been observed in the tidal portion near the D.C.-Md. Line. This large increase, especially during high flows, can be attributed to defective sewerage systems of the Washington Suburban Sanitary Commission. Data for the month of June 1969, presented in Table III, document these high concentrations.

Associated with decreases in turbidity or suspended sediments in the tidal system is a decrease in phosphorus which is also shown in Table III. This adsorption phenomonon of phosphorus onto silt particles has also been demonstrated recently in both laboratory and field measurement by the Chesapeake Technical Support Laboratory as part of a nutrient transport study in the Potomac Estuary.

TABLE II

NUTRIENT CONCENTRATIONS AND LOADINGS
BLADENSBURG ROAD BRIDGE, ANACOSTIA RIVER
1966

Month	Average Monthly River Discharge (cfs)	T. PO_4 as PO_4 (mg/l)	(lbs/day)	NO_3 as N (mg/l)	(lbs/day)	TKN (mg/l)	(lbs/day)
January	50	1.27	342	1.17	315	1.44	387
February	200	0.67	721	1.12	1205	1.54	1657
March	88	0.38	180	0.93	440	1.40	663
April	132	0.47	334	0.63	447	1.45	1030
May	125	0.74	498	1.11	746	1.11	746
June	42	0.31	70	0.66	149	1.10	249
July	18	0.96	93	0.52	50	1.33	129
August	15	0.96	77	0.52	42	1.32	107
September	232	0.50	624	0.90	1123	0.46	574
October	163	1.04	912	1.27	1114	1.68	1473
November	46	1.79	443	0.57	141	1.45	359
December	71	0.51	195	1.00	382	0.59	225
Monthly Average	98.5	0.80	374	0.86	513	1.24	633

TABLE III

Anacostia Tidal River System
D.C. Water Pollution Control Division Data

MONTHLY REPORT
June 1969

Sampling Station	Total P as PO_4 (mg/l)	TKN as N (mg/l)	NO_2+NO_3 as N (mg/l)	NH_3-N (mg/l)	Turb (units)
D. C. Line	6.10	2.14	0.59	1.18	226
Ben. Rd.	4.81	2.23	0.41	0.63	197
E. Cap. St.	2.74	2.18	0.40	1.10	161
Pa. Ave.	1.16	1.85	0.30	1.80	53
11th St.	1.03	1.97	0.33	1.80	40
S. Cap. St.	1.09	2.15	0.20	1.41	18
Wash. Ch.	0.81	1.73	0.31	0.86	9

4. Sediments and Turbidity

The Anacostia River can usually be characterized as a muddy stream. During periods of high stream flow, large quantities of silt and debris are carried downstream to the Potomac.

Sediment data obtained by USGS for the Colesville, Maryland station, located in the Northwest Branch, indicate concentrations over 4,300 ppm at times. The 1967 to 1968 sediment yield for the Colesville station, which has a drainage area of 21.1 square miles, is given below:

Year	River Discharge (cfs-day)	Sediment (tons/year)
1963	5387	16811
1964	6844	11596
1965	5068	15889
1966	5137	14402
1967	6738	15009
1968	6188	10498

Using an average sediment tonnage of 14,000 at this station, the estimated silt contribution for the entire watershed is about 114,000 tons/year.

The effect of the sediment loadings on the turbidity in the tidal system is shown in Figure VII. The higher concentrations of turbidity near the D.C.-Md. Line are decreased significantly downstream, especially at the South Capitol Street Bridge station. The decrease in turbidity is also reflected in the monthly summary as shown in Table III.

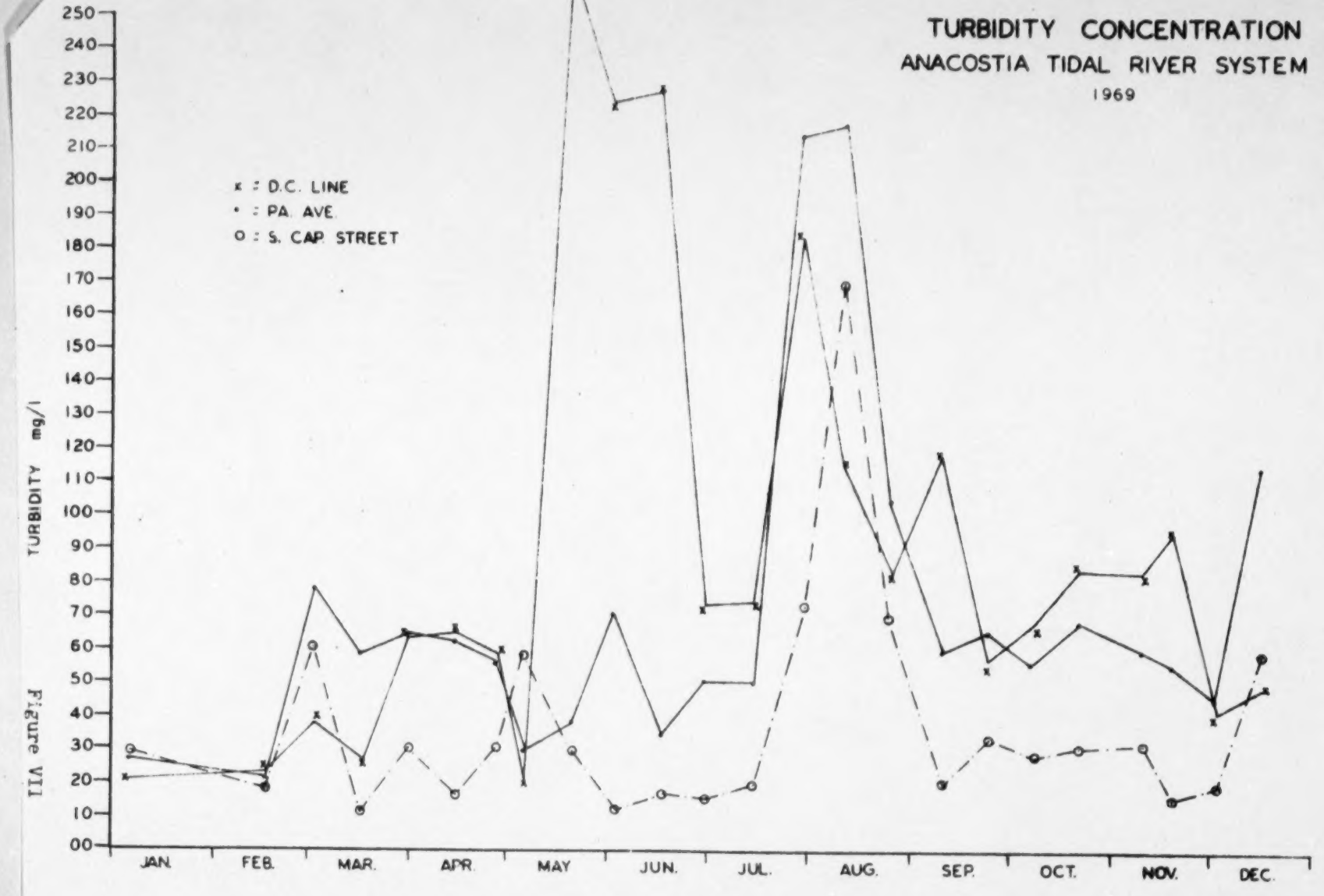

TURBIDITY CONCENTRATION
ANACOSTIA TIDAL RIVER SYSTEM
1969
x : D.C. LINE
• : PA. AVE.
o : S. CAP. STREET
TURBIDITY mg/l
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
00
JAN.
FEB.
MAR.
APR.
MAY
JUN.
JUL.
AUG.
SEP.
OCT.
NOV.
DEC.

Figure VII

D. POPULATION AND WASTEWATER PROJECTIONS

1. Anacostia Valley

The area which could be served by a wastewater renovation facility located upstream from the D.C.-Md. Line would be the Anacostia Valley located in Prince Georges and Montgomery Counties. Population projections for the Anacostia and Beaverdam Valleys of the two counties have been developed jointly by the Washington Suburban Sanitary Commission and the Maryland-National Capital Park and Planning Commission and are given below:

Year	Montgomery (Anacostia)	Prince Georges (Anacostia)	Prince Georges (Beaverdam)	Total Population
1967	131,400	197,400	64,200	393,000
1980	167,800	237,700	81,800	487,300
2000	228,600	313,800	100,900	643,300
Capacity	453,400	390,500	122,700	966,600

These figures were obtained from the current "Ten Year Water and Sewerage Plan" of the Washington Suburban Sanitary Commission for Prince Georges County.

Data from a 1968 report prepared for WSSC by Whitman, Requardt, and Associates indicate that the population for the Anacostia Valley is considerably higher. Their analysis shows the following:

Year	Population
1968	500,000
1980	850,000
2000	1,000,000

A request was made to the Maryland-National Capital Park and Planning Commission to update their projections. Their recent projections are given below:

Year	Population
1970	466,000
1980	661,000
2000	744,000
2020	837,000

Utilizing an average of the wastewater volumes and constituents obtained in the 1969 surveys [1] and the above populations, discharge volumes, BOD, phosphorus and nitrogen loadings before treatment were projected as follows:

Year	Population	Volume (mgd)	BOD (lbs/day	Phosphorus as P (lbs/day)	T. Nitrogen as N (lbs/day)
1970	466,000	55	69,200	4,320	9,830
1980	661,000	78	99,150	5,949	13,881
2000	744,000	88	111,600	6,696	15,624
2020	837,000	99	125,550	7,533	17,577

2. District of Columbia

The projected population, wastewater volume, and BOD loadings, as determined by Metcalf and Eddy, Engineers, in February 1969 for the Blue Plains Treatment Plant of the District of Columbia are presented below:

Year	Population	Volume (mgd)	BOD (lbs/day)	Suspended Solids
1970	1,750,000	232	304,000	378,000
1980	2,227,000	309	490,000	537,000
2000	3,122,000	419	718,000	843,000

If the wastewater from the Anacostia Valley is treated by a separate facility, the following reductions in flow at the Blue Plains Treatment Plant were estimated:

Year	Blue Plains* (mgd)	Anacostia Valley (mgd)	% of Blue Plains Flow
1970	177	55	31
1980	231	78	34
2000	331	88	27

* Excluding Anacostia Flows

CHAPTER IV

WASTEWATER ASSIMILATION AND TRANSPORT ANALYSIS

The five major physical factors which govern the wastewater assimilation and transport capabilities are:

1. Stream flow conditions including flow-wastewater volume ratio,
2. Residence flushing time of the tidal system,
3. Tidal hydrodynamics including dispersion,
4. Reaeration and decay rates on dissolved oxygen budget, and
5. Turbidity and algal growth.

Factors which affect the assimilation and transport capacities other than waste loadings are:

1. Storm sewer discharges,
2. Combined sewer discharges located between East Capitol Street and Sousa Bridges and near the 11th Street Bridge,
3. Defective sanitary sewerage systems,
4. Benthic demand of organic deposits in the bottom muds, and
5. Land runoff.

Water quality data presented in the previous chapter indicate that under current sanitary practices, the tidal portion of the Anacostia River is receiving more oxygen demanding wastes than it can assimilate during the months of July, August, and September.

While nutrient concentrations, both nitrogen and phosphorus, are manyfold above the minimum level associated with excessive algal blooms,

the growths are not as pronounced as those of the 1950's as reported by Bartsch [2] and Stotts and Longwell [3]. Reduction in algal growths can be primarily attributed to lack of light penetration resulting from high turbidities and to the elimination of discharges from the Bladensburg wastewater treatment facility of WSSC.

Preliminary analysis of the assimilation and transport capacity of the tidal system was made using two separate mathematical models developed by Thomann [4] and by Water Resources Engineers, Inc. (WRE) [5]. The segmentation of the tidal system for the Thomann model is shown in Figure VIII with detailed data presented in Table IV. Detailed explanation of the two mathematical models is beyond the scope of this report.

A. STREAM FLOW - WASTEWATER FLOW ANALYSIS

Water quality standards are applicable to river discharges equal to or greater than the 7-day low flow with a recurrence interval of once-in-ten-years. For the Anacostia tidal system this flow is 8 cfs.

For 1968 and the three population benchmarks, the wastewater and river discharges including the ratio of wastewater stream discharge are presented below:

Year	River Discharge* (cfs)	Wastewater Discharge (mgd)	Ratio of Waste to/Stream Discharge
1970	8	55	19.6
1980	8	78	15.1
2000	8	88	17.0
2020	8	99	19.2

* 7-day low flow with recurrence interval of once-in-ten-years

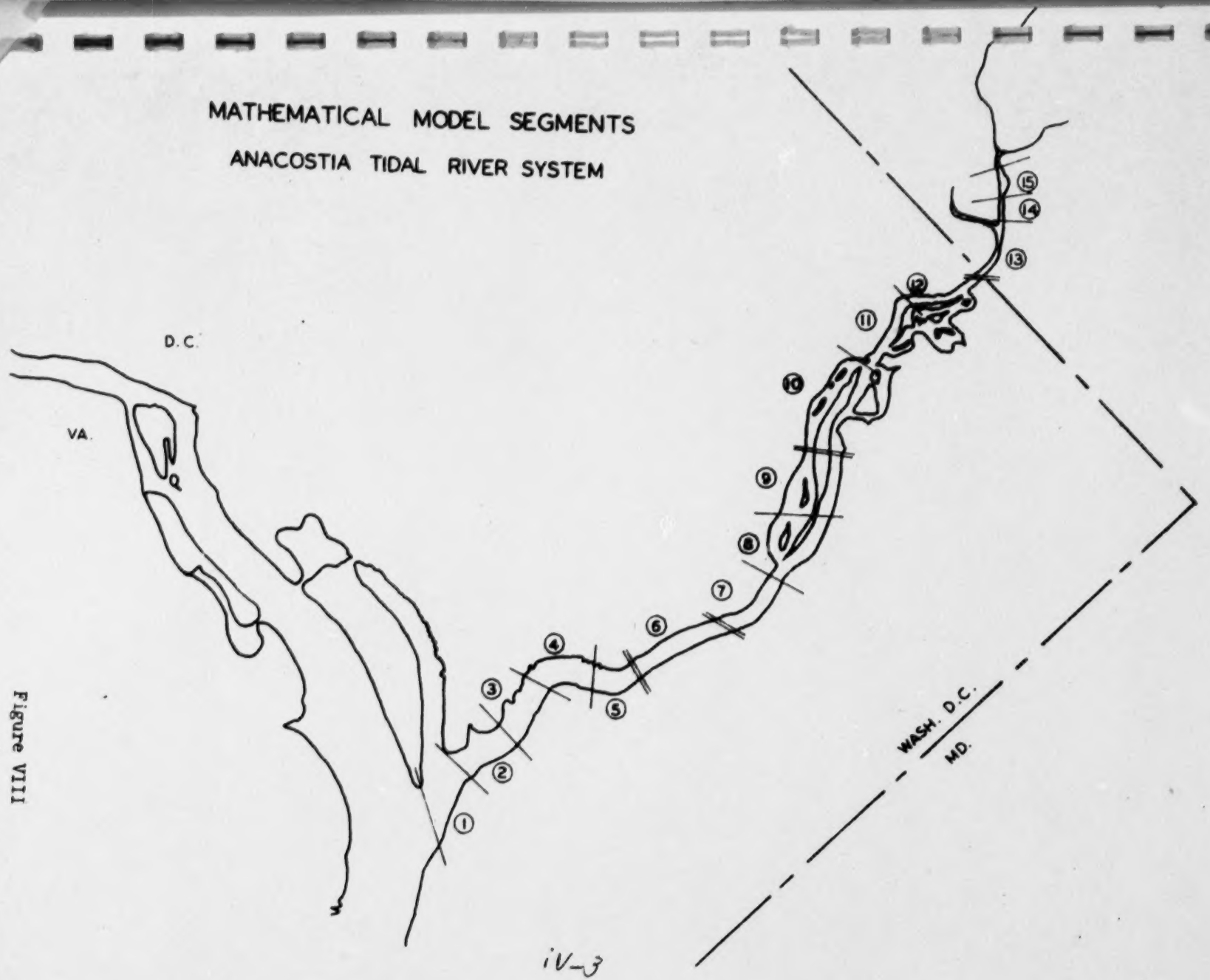

MATHEMATICAL MODEL SEGMENTS
ANACOSTIA TIDAL RIVER SYSTEM
D.C.
VA.
WASH. D.C.
MD.
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

Figure VIII

TABLE IV

MATHEMATICAL MODEL SEGMENTATION
Anacostia Tidal River System
Mean Water Data *

Segment Number	Interface Areas Upper (ft^2)	Interface Areas Lower (ft^2)	Interface Widths Upper (ft)	Interface Widths Lower (ft)	Length (ft)	Volume ($ft^3 \times 10^6$)	Surface Area ($ft^2 \times 10^6$)	Depth (ft)
1	31,290	58,060	1500	3200	2900	129.55	4.96	26.11
2	27,100	31,290	1250	1500	2380	69.48	3.24	21.44
3	27,100	27,100	1250	1250	2380	64.49	2.68	24.06
4	24,710	27,100	1150	1250	2640	68.38	3.20	21.36
5	14,450	24,710	750	1150	2640	51.69	2.36	21.90
6	8,580	14,450	750	750	3430	39.84	2.80	14.22
7	8,645	8,580	750	750	3430	29.53	2.44	12.10
8	3,095	8,645	550	750	3170	18.60	1.76	10.56
9	4,805	3,095	400	550	2900	11.45	1.36	8.41
10	2,840	4,805	350	400	3960	15.13	1.32	11.46
11	3,195	2,840	300	350	3170	9.56	1.00	9.56
12	3,000	3,195	300	300	3430	10.62	1.04	10.21
13	3,030	3,000	250	300	2900	8.74	0.80	10.92
14	1,775	3,030	250	250	2640	6.34	0.60	10.57
15	775 **	1,775	200	250	2640	5.20	1.00	5.20

* Data based on soundings made April 1970.
** Marina 2,710
@1,500

1,000
@1,140

B. RESIDENCE OR FLUSHING TIME

Assuming a base flow of 8 cfs and wastewater discharges of 50, 100, and 150 mgd and the volume of the tidal system of 540,000,000 cubic feet, the residence time of the Anacostia as given below has been computed by a volume displacement analysis and by using the WRE mathematical model:

River Flow (cfs)	Wastewater Discharge (cfs)	(mgd)	Total Flow (cfs)	Computed Residence Time (days)	WRE Model Residence Time (days)
8	0	0	8	781	30
8	77	50	85	73	19
8	154	100	162	38	15
8	231	150	239	27	12

The effect of the increase in river discharge on the WRE model residence time for the entire system is shown in Figure IX.

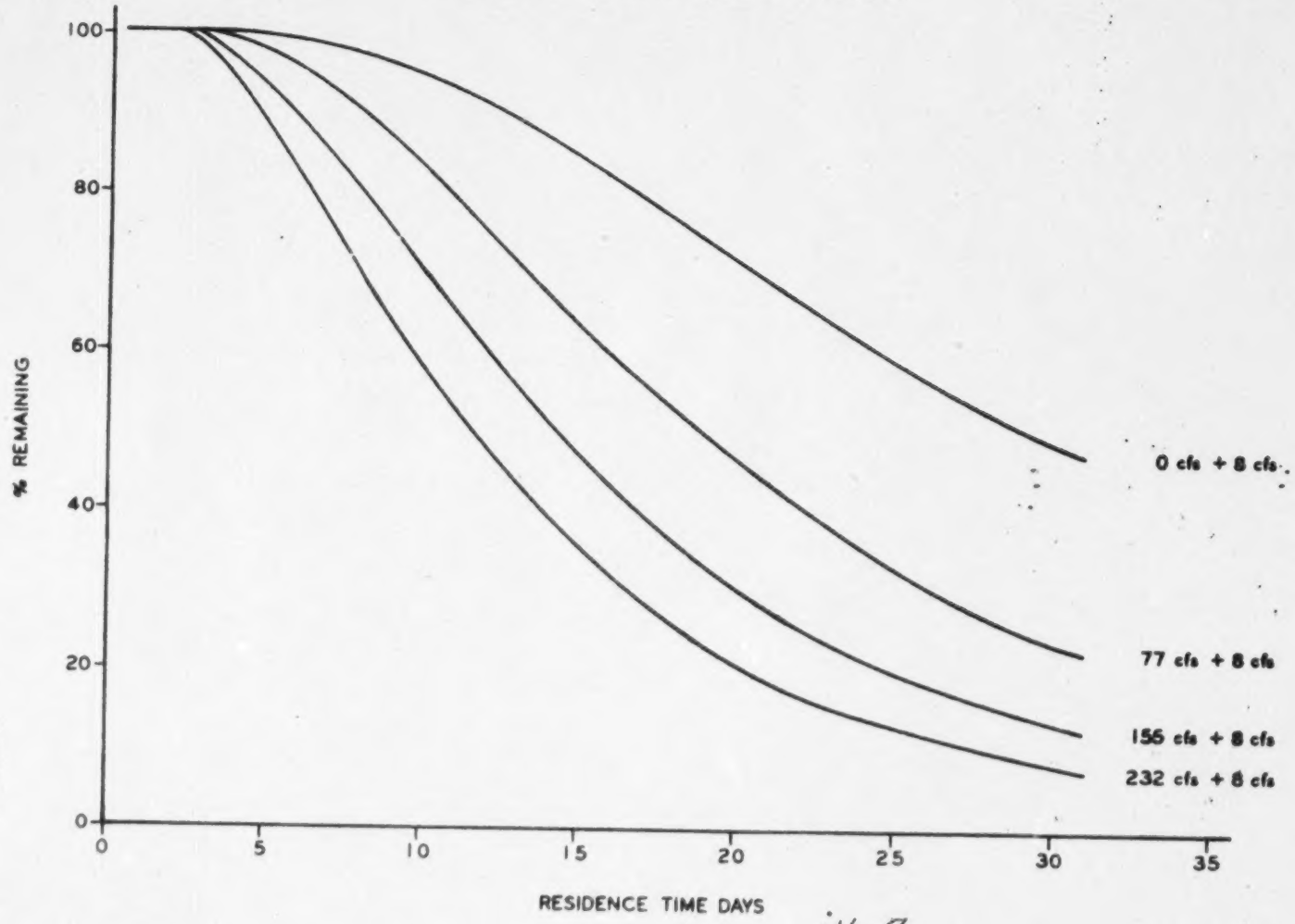
The computed residence time based on complete volume displacement ignores all mixing and transport of quality constituents due to tidal action and thus only provides an extremely rough estimate of the actual residence time. Such a computation is particularly misleading at very low inflow rates (as indicated by the 781 days residence time for the 8 cfs flow rate). As the inflow approaches zero the computed residence time approaches infinity while in the prototype there is always significant mixing and transport due solely to tidal action. The residence times predicted by the model include these factors.

With the residence time of two weeks, nearly all of the nitrogenous and carbonaceous BOD will be exerted in the Anacostia tidal system.

Therefore, there will be very little effect under low flow conditions on the oxygen resources of the main Potomac from a discharge in the Anacostia at the site investigated.

RESIDENCE TIME FOR VARIOUS WASTEWATER FLOWS

ANACOSTIA TIDAL RIVER SYSTEM



C. TIDAL HYDRODYNAMICS

The cross-sectional area of the Anacostia tidal system can be mathematically expressed by the following equation:

$$A_x = A_o e^{ax}$$

where:

A_x = cross-section at point x

A_o = cross-section at x = o

a = exponent (slope of curve describing A as function of x)

x = distance along the river

Using the above expression, the steady-state equation for a conservative substance was used to determine the dispersion coefficient required in the Thomann mathematical model. The equation is given below:

$$Cx = Co\, e^{\frac{Q}{a\ A_o\ E}(1-e^{-ax})}$$

where:

C_x = concentration at point x

C_o = concentration at x = o

E = dispersion coefficient

Other variables as previously defined

Two methods of determining the dispersion coefficients are by use of either salinity or dye tracer data. However, since this area is not saline and since the dye study, which was initiated in the latter part of April 1970 would not be completed in time for this report, alkalinity data were utilized for dispersion studies. The

natural alkalinity difference of about 50 mg/l between the Potomac and the Anacostia was adequate for this purpose and incorporated into the above formulations. Dispersion coefficients, for the various model segments throughout a range of river discharges, are given in Figure X.

For total river discharges of 58, 108, and 208 cfs, the effect of the dispersion coefficient on the simulated profiles using the Thomann steady state model can be seen in Figures XI, XII, and XIII, respectively. At the higher flows, the effect on the simulated profile is not as significant as during lower flows.

Figure XIV shows simulated profiles for various wastewater discharge rates using the Thomann model with the dispersion coefficients as given in Figure X and considering a conservative pollutant. A sharp decrease in the simulated profile occurs at model segment 8 or at the lower end of Kingman Lake. The volume of the tidal system increases rapidly in this reach.

Simulated profiles for a nonconservative pollutant such as BOD, as presented in Figure XV, show an even smaller response to the dispersion coefficient. The sensitivity of the nonconservative simulated profile to the decay rate of a pollutant is also an indication of a high residence time in the tidal system.

Expanded scale simulated profiles for conservative and nonconservative pollutants are shown in Figure XVI. A 1000 lbs/day discharge at the site investigated will increase the concentrations of conservative and nonconservative pollutants in model segment 8 to

approximately 0.5 and 0.2 mg/l, respectively. Dissolved oxygen in this segment is the most depressed, often with concentrations near 1.0 mg/l under summer conditions.

DISPERSION COEFFICIENT vs FLOW
ANACOSTIA TIDAL RIVER SYSTEM
1969 D.C. ALKALINITY DATA

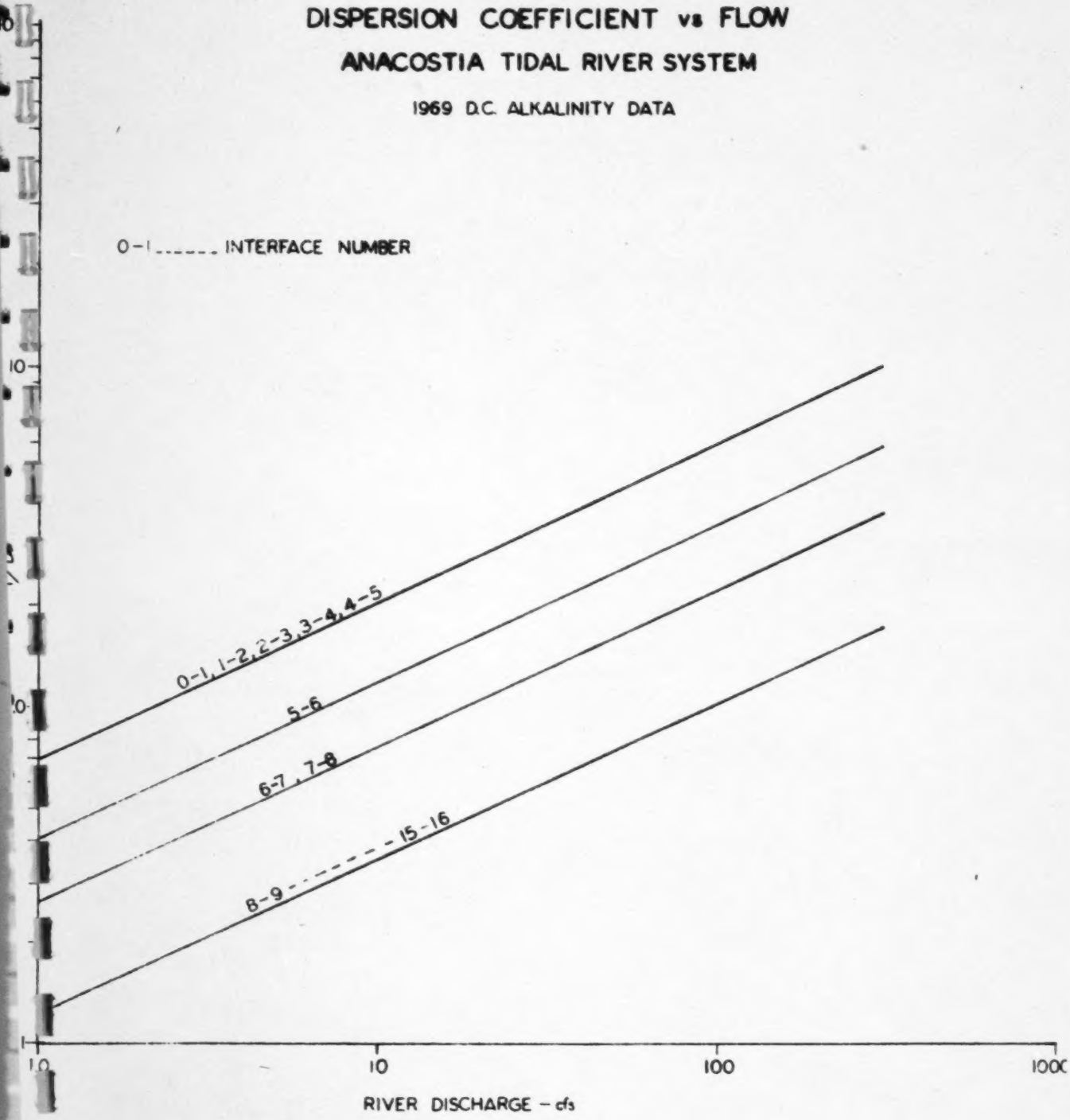
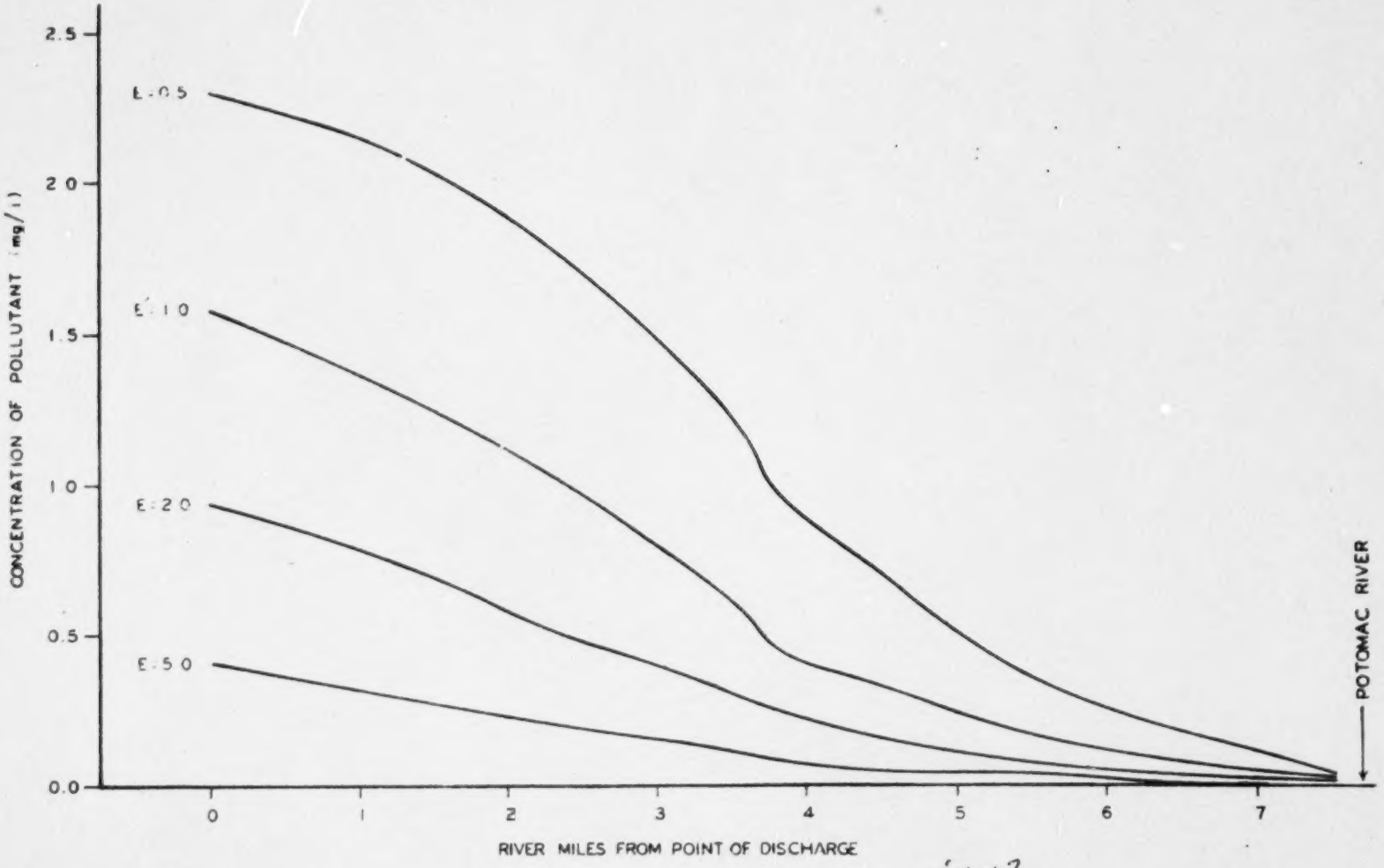


Figure V


2.5
2.0
1.5
1.0
0.5
0.0
E-05
E-10
E-20
E-50
CONCENTRATION OF POLLUTANT (mg/l)
0
1
2
3
4
5
6
7
RIVER MILES FROM POINT OF DISCHARGE
POTOMAC RIVER

IV-12

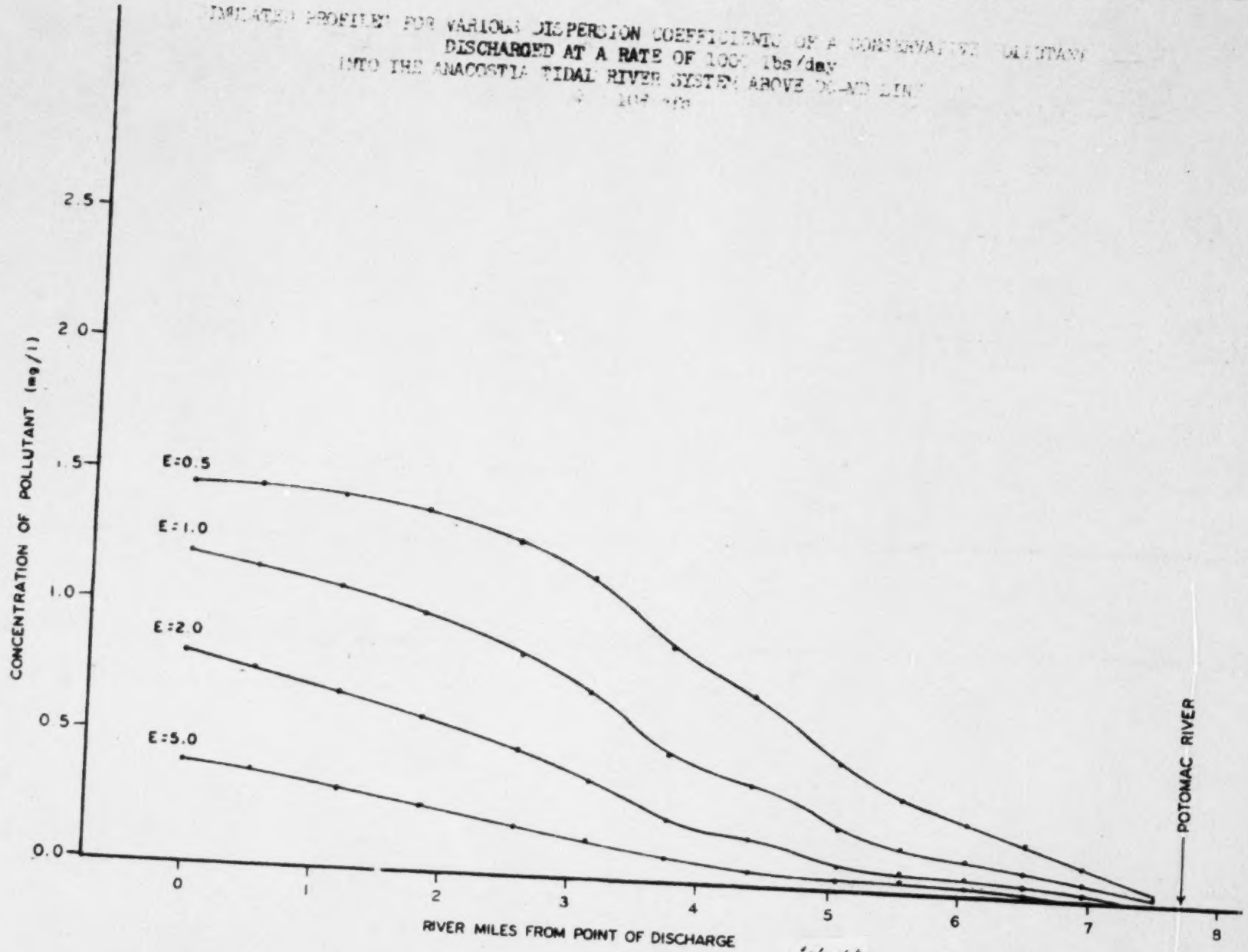


FIGURE XII

IV-13

SIMULATED PROFILES FOR VARIOUS DISPERSION COEFFICIENTS OF A CONSERVATIVE POLLUTANT DISCHARGED AT A RATE OF [illegible] lbs/day INTO THE ANACOSTIA TIDAL RIVER SYSTEM ABOVE DC-MD LINE

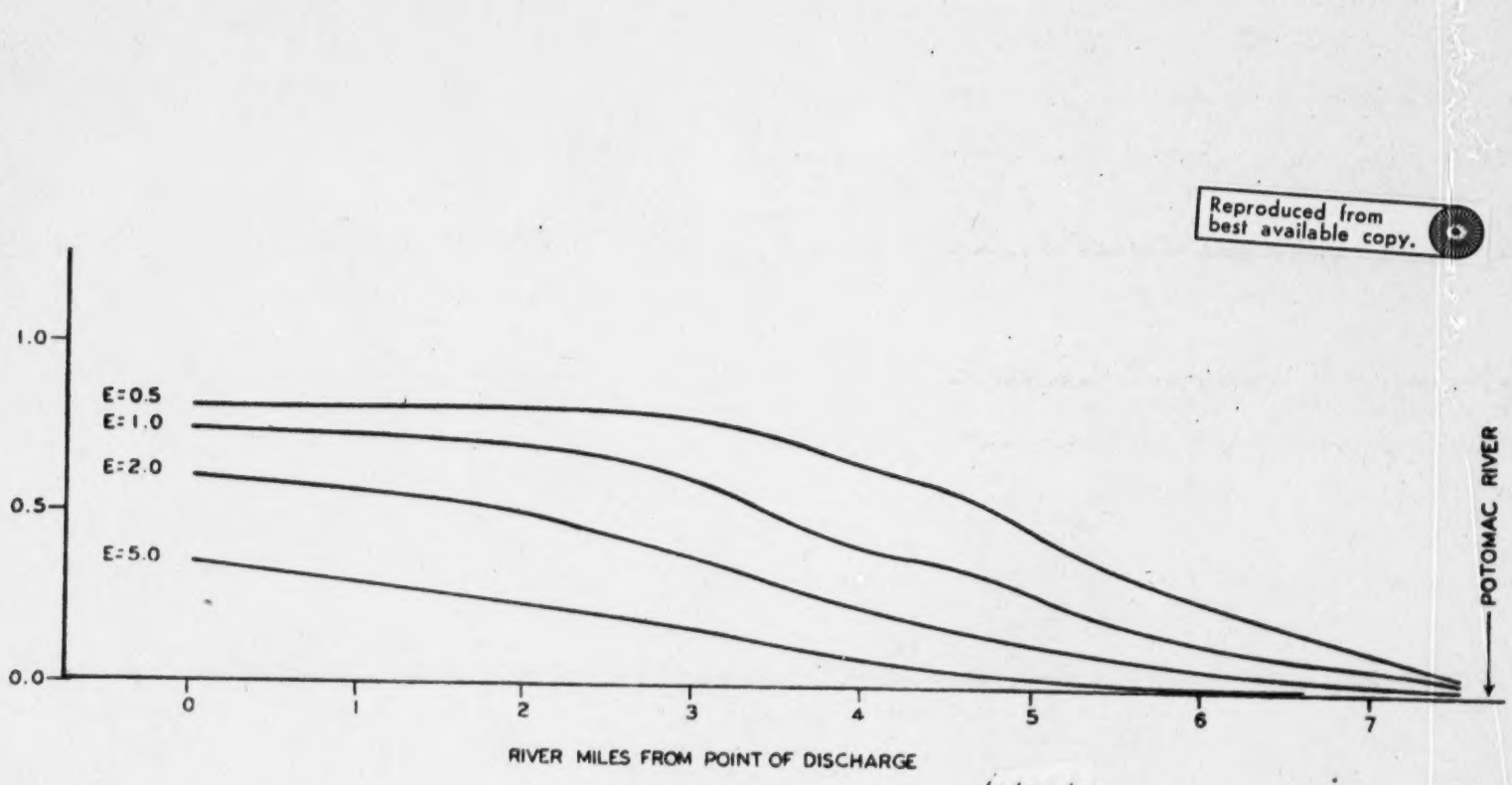


FIGURE XIII

Reproduced from best available copy.

11-14

SIMULATED PROFILES FOR VARIOUS WASTEWATER DISCHARGE RATES
FOR CALCULATED DISPERSION COEFFICIENTS OF A CONSERVATIVE POLLUTANT
DISCHARGED AT A RATE OF 1000 lbs/day
INTO THE ANACOSTIA TIDAL RIVER SYSTEM ABOVE DC-MD LINE

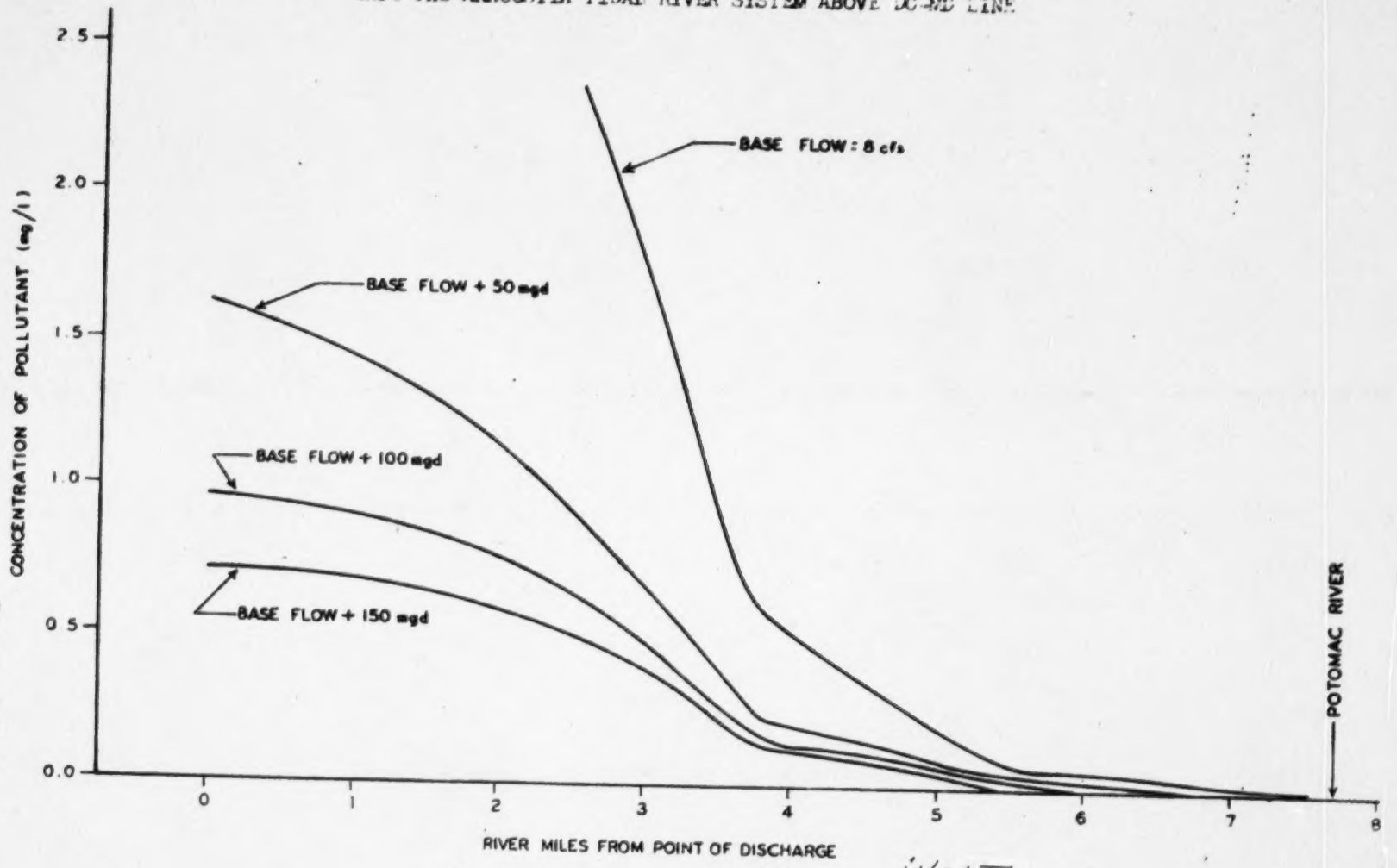


Figure XIV

[redacted] FOR [redacted] DISPERSION COEFFICIENTS OF A NONCONSERVATIVE POLLUTANT
DISCHARGED AT A RATE OF 1000 lbs/day
INTO THE ANACOSTIA TIDAL RIVER SYSTEM ABOVE THE DC-MD LINE
Q = 108 cfs
Decay Rate = 0.3 (base e)

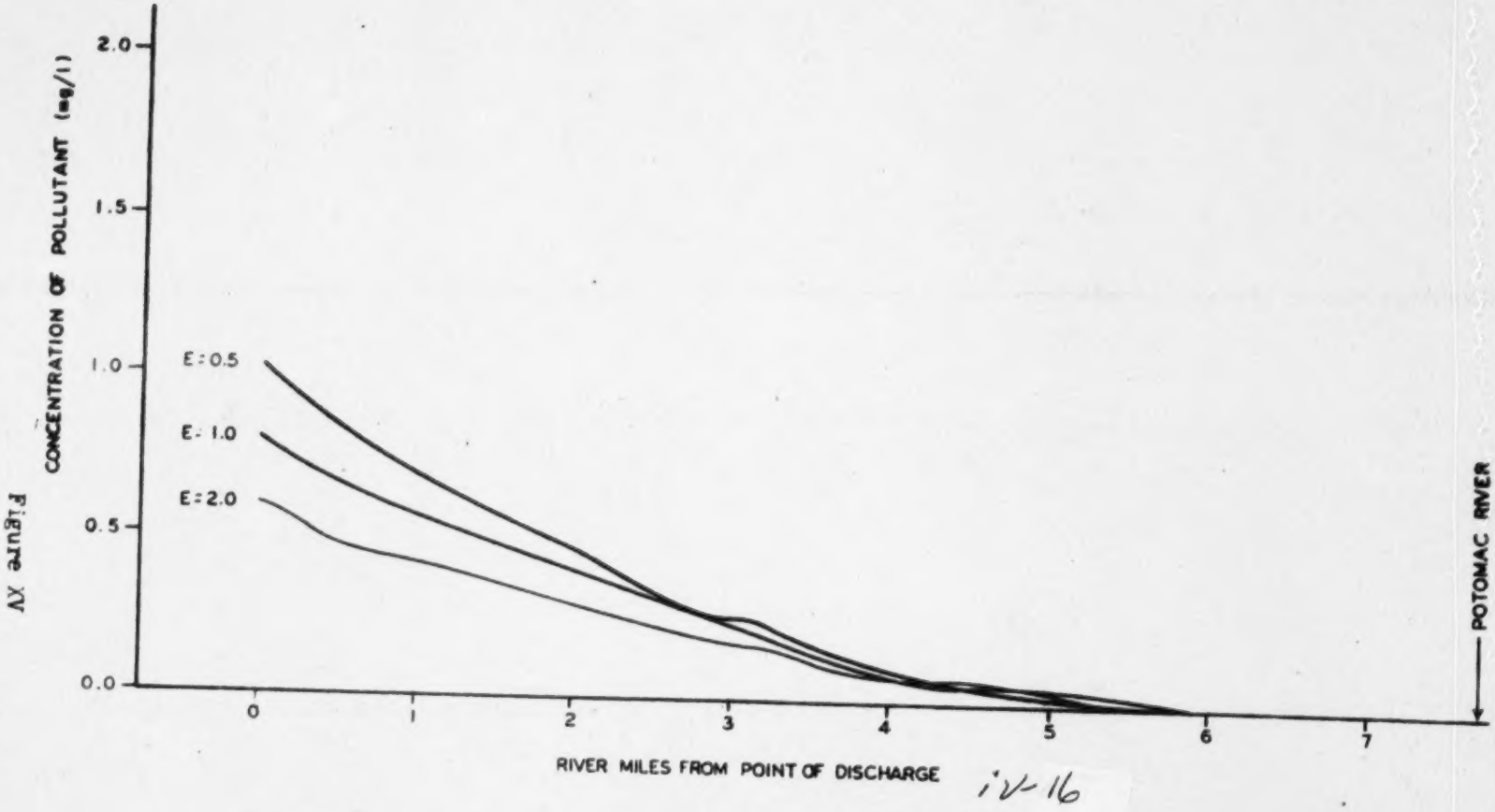


FIGURE XV

IV-16

D. SELF-PURIFICATION AND THE DISSOLVED OXYGEN BUDGET

In the tidal system, carbonaceous and nitrogenous BOD from land runoff, storm sewers, defective sanitary systems was large enough at times to depress the DO below 2.0 mg/l in the area of Kingman Lake.

Preliminary model studies using the WRE hydrodynamic model indicate that even with large wastewater discharges, there would be no appreciable increase in self-purification or reaeration rates because of insignificant changes in the advective tidal velocities. Hence, it appears that a discharge into the Anacostia would have to contain a BOD (both carbonaceous and nitrogenous) concentration equal to or lower than that currently found in the tidal system. For the critical months, the effluent should be renovated to have a BOD_5 of 2.0 to 4.0 and an unoxidized nitrogen concentration of 0.5 to 1.0 mg/l.

Another important aspect of the wastewater treatment facility in terms of water quality enhancement of the receiving water will be the DO in the final effluent. For a wastewater discharge of 100 mgd, nearly all of the advective river flow will be from the wastewater. Therefore, a minimum of 4.0 mg/l should be maintained in the final effluent at all times. If a 6.0 mg/l concentration of DO is maintained in the effluent, along with a low oxygen demand, the wastewater could enhance present water quality in the Anacostia River.

An example of this enhancement can be readily shown by utilizing the simulated curves in Figure XVI. With an effluent DO of 4.0 mg/l, the DO at the critical sag point will be increased by 2.0 mg/l (0.5 x 4.0) with resulting DO being about 3.0 mg/l. If the effluent

SIMULATED PROFILES FOR A CONSERVATIVE AND NONCONSERVATIVE POLLUTANT
DISCHARGED AT A RATE OF 1000 lbs/day
INTO THE ANACOSTIA TIDAL RIVER ABOVE THE DC-MD LINE
Wastewater Flow - [illegible]
River [illegible] cfs

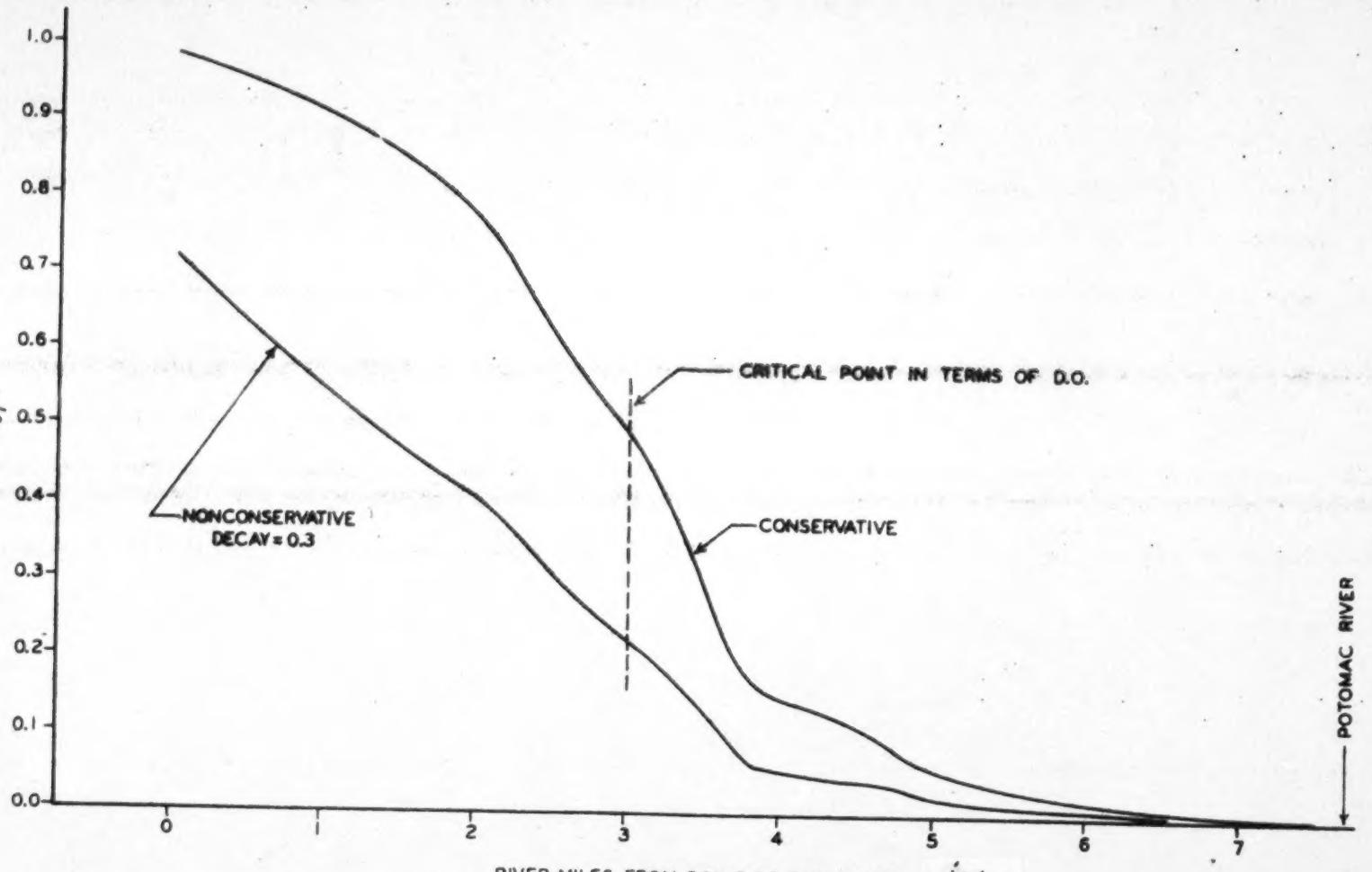


Figure XVI

has 6.0 mg/l, or approximately 5,000 lbs/day of oxygen, the DO at the critical point will be increased by approximately 3.0 mg/l. This assumes that reaeration from the atmosphere is equal to the oxygen demand of the wastewater (The DO during the summer months of 1969 was about 1.0 mg/l in this area). The resulting DO in the system from the 6.0 mg/l would then be approximately 4.0 mg/l (3.0 + 1.0), thus meeting the DO water quality standard.

E. NUTRIENTS AND ALGAL GROWTH

As indicated earlier in this chapter, algal growths were abundant in the Anacostia in the 1950's. Lack of nuisance blooms during the spring and summer months in the 1960's appear to have been a result of low light penetration and the elimination of the Bladensburg Wastewater Treatment Facility.

If a wastewater effluent of 100 mgd of highly treated effluent including low turbidities were to be discharged into the Anacostia above the D.C.-Md. Line, a significant increase in light penetration will occur. Such an increase could cause nuisance algal growth in the Anacostia.

To reduce the incidence and magnitude of nuisance algal growth in the upper Potomac tidal system, upper limits of 0.1 and 0.5 mg/l of phosphorus as P and nitrogen respectively were used to calculate maximum permissible nutrient loadings from wastewater discharges. Since most of the advective flow would be from wastewater, the nutrient concentrations in any Anacostia effluent should be similar to these limits. Allowing for possible continued reduction in light penetration, a range of these nutrient limits was utilized. The phosphorus limits used were 0.1 to 0.2 mg/l with nitrogen limits of 0.5 to 1.0 mg/l.

F. TREATMENT AT THE BLUE PLAINS PLANT VERSUS CONSTRUCTING A FACILITY IN THE ANACOSTIA VALLEY

The Potomac River-Washington Metropolitan Area Enforcement Conference on May 8, 1969, agreed upon a BOD loading of 16,500 lbs/day, a nitrogen loading of 8,000 lbs/day, and a phosphorus loading of 740 lbs/day. Based on 1968 contributions, the Blue Plains Treatment Plant was allocated 12,700, 6,130, and 560 lbs/day of BOD_5, nitrogen, and phosphorus, respectively. Using the current loading rates and population projections, the removal percentage and effluent concentrations were determined as given below:

	1970 Q = 232 mgd		1980 Q = 309 mgd		2000 Q = 419 mgd	
	Removal (%)	Conc. Effl. (mg/l)	Removal (%)	Conc. Effl. (mg/l)	Removal (%)	Conc. Effl. (mg/l)
BOD_5	95.8	6.50	97	4.90	98	3.60
Nitrogen	86.6	3.20	90	2.40	93	1.80
Phos. as P	96.6	0.28	97	0.22	98	0.16

The effluent from the 419 mgd facility would have to be renovated to such a high degree, except for nitrogen, that it could be considered as approaching ultimate wastewater treatment (UWT*).

* Ultimate wastewater treatment can be defined as renovation of the wastewater to such a degree that it can be discharged into the receiving stream in unlimited quantities without restriction of intended use of the water resource due to the lack of needed assimilative or transport capability of the stream.

Wastewater constituents before treatment, effluent concentrations, and percent removal requirements for a discharge into the Anacostia at the site investigated are presented below:

Parameter	Wastewater Consitituents Before Treatment (mg/l)	Effluent Concentrations (mg/l)	Percent Removal Requirements
BOD_5	200.0	2.0 - 4.0	98 - 99
T. Phosphorus as P	11.0	0.1 - 0.2	98 - 99
T. Nitrogen as N	22.0	0.5 - 1.0	96 - 98

In incorporating UWT into a water quality management program, the effluent standard concept is utilized. For receiving waters such as the tidal portion of the Anacostia River, this concept appears to be realistic under present conditions to enhance the dissolved oxygen resources and to prevent nuisance algal growths.

If an effluent of this quality is maintained during the critical times of the year, the UWT concept can be applied to the tidal portion of the Anacostia River. With this concept, the effluent will be of higher quality than the existing water quality in the Anacostia and thus will enhance the water quality providing a positive water quality management approach.

Even with the high waste removal requirements, a major uncertainty is the possibility of nuisance algal blooms stimulated by favorable growing conditions in the tidal system. Data obtained by CTSL from the tidal waters of the Anacostia, which are shallow, with little

freshwater inflow and insignificant transport indicate that such areas have higher growths at the same nutrient levels for a given area than along the main stem of the Potomac. While light penetration inhibition may reduce this potential somewhat in the Anacostia, nevertheless, the potential remains. Discharges into the main Potomac have a decreased algal growth potential per square foot area because of the greater depths.

G. Continuing Studies

Additional studies relating to (1) tidal dispersion characteristics of the Anacostia River, (2) water quality interactions between Kingman Lake and the Anacostia River, and (3) further definition of the DO budget including reaeration rates and benthic demands are already in progress or will be initiated by CTSL in the coming months.

As mentioned earlier in this report, a dye tracer investigation of the Anacostia River was conducted from April 22-28, 1970. While the data collection phase of this study has not been completed, preliminary analyses indicate that (1) dye movement and residence time closely parallels mathematical model predictions, and (2) a considerable dye buildup was observed in Kingman Lake which further demonstrates that its water quality is significantly dependent on the Anacostia's quality. The final results of this dye study will be incorporated into the next progress report for the Potomac River-Washington Metropolitan Area Enforcement Conference. They will also be published in a separate report entitled "Potomac-Anacostia Rivers Dye Studies."

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APPENDIX A

ANACOSTIA RIVER STUDY
CHESAPEAKE FIELD STATION
1967

Date Sample Taken	DO mg/l	Turb. JTU	LAS/ABS mg/l	BOD mg/l	Susp. Sol. mg/l	Vol. Sol. mg/l	Coliform MPN	Fecal Coliform MPN
				INDIAN CREEK - BELTSVILLE				
4-17	9.19	4.0	ND	4.55	8.4	4.8	17,200	1,090
4-18	9.25	13.0		8.26	12.0	8.5	7,000	1,300
4-19	8.25	5.3		8.27	7.2	3.6	< 200	< 200
4-20	10.85	5.2	.300	8.16	4.0	5.0	790	170
4-20	8.17		.450					
4-21	8.51	6.7		8.04	5.0	--	50	< 20
				LITTLE PAINT BRANCH - CHERRY HILL				
4-17	10.17	6.2	ND	2.30	10	6.0	490	230
4-18	10.87	15.0	.250	1.94	10.5	2.0	17,200	1,720
4-19	10.50	13.0		1.81	5.0	1.5	3,300	1,410
4-20	11.21	6.1	ND	1.53	9.6	4.4	200	< 200
4-20	9.84		.250					
4-21	10.65	5.6		1.31	4.8	2.0	80	< 20
				PAINT BRANCH - PLANT INDUSTRY STATION				
4-17	10.79	2.7	.250	1.80	8.8	6.8	310	130
4-18	9.95	10.0		2.04	9.0	7.5	2,200	330
4-19	11.73	4.4		1.52	4.0	1.0	790	220
4-20	11.97	6.7	ND	1.30	11.6	4.8	490	230
4-20	11.29		ND					
4-20	10.92		.230					
4-21	11.46	5.7		1.21	5.6	2.0	220	130
				PAINT BRANCH - STEWART CHAPEL				
4-17	10.26	2.7	ND	1.54	11.6	7.6	170	20
4-18	10.79	10.0	ND	1.06	3.0	--	17,200	790
4-19	10.70	3.4		1.41	3.5	1.0	940	330
4-20	11.02	2.3	ND	.85	.8	--	260	40
4-20	9.88		.240					
4-21	10.53	13.0		1.20	2.8	--	790	< 20

ND - Not detectable

Date Sample Taken	DO mg/l	Turb. JTU	LAS/ABS mg/l	BOD mg/l	Susp. Sol. mg/l	Vol. Sol. mg/l	Coliform MPN	Fecal Coliform MPN
			PAINT BRANCH - COLLEGE PARK					
4-17	10.80	4.6	.250	2.46	8.4	3.2	7,900	1,300
4-18	10.49	13.0		2.43	20.0	2.0	> 7,900	> 790
4-19	11.49	7.6		1.85	7.0	.5	13,000	3,480
4-20	12.00	7.2	.200	1.17	14.0	8.8	13,000	9,180
4-21	11.26	5.5		1.41	2.8	--	1,720	170
			INDIAN CREEK - BERWYN HEIGHTS					
4-17	8.77	43.0	LA	3.61	44.0	5.4	700	700
4-18	8.17	49.0	.260	3.33	67.0	11.0	10,900	3,300
4-19	9.40	60.0		7.63	61.0	10.0	940	330
4-20	9.82	33.0	ND	3.97	38.0	11.0	790	330
4-21	9.06	78.0		3.19	74.0	5.0	2,400	140
			NORTHWEST BRANCH - COLESVILLE					
4-24	10.48	4.2	ND	2.54	.8	2.0	1,090	170
4-25	12.36	4.9	ND	2.10	6.4	1.2	80	80
4-26	11.56	4.8		1.86	2.6	.8	490	490
4-27	10.57	21.0		2.21	16.4	4.4	5,420	1,090
4-28	11.88	6.8		1.91	6.0	.8	2,400	790
			NORTHWEST BRANCH - NEW HAMPSHIRE AVE.					
4-24	11.13	4.6	.513	2.80	--	2.4	3,480	460
4-25	12.35	5.4	ND	1.81	7.2	4.4	1,300	500
4-26	11.87	3.5		1.69	5.2	4.8	170	< 20
4-27	11.08	14.0		2.58	10.0	10.0	3,300	3,300
4-28	12.42	6.7		1.61	5.6	3.6	460	210
			NORTHWEST BRANCH - LEWISDALE (E.W. HWY)					
4-24	10.79	4.0	ND	2.60	--	--	700	230
4-25	12.22	3.2		1.94	4.0	--	330	130
4-26	11.71	2.9		1.84	--	2.4	130	130
4-27	10.69	17.0		2.64	9.6	2.4	3,480	3,480
4-28	11.83	7.2		2.53	10.4	6.0	790	490

ND - Not detectable
LA - Lab accident

Date Sample Taken	DO mg/l	Turb. JTU	LAS/ABS mg/l	BOD mg/l	Susp. Sol. mg/l	Vol. Sol. mg/l	Coliform MPN	Fecal Coliform MPN
				SLIGO CREEK - SLIGO				
4-24	8.63	17.0	.600	9.46	4.0	3.6	54,200	9,180
4-25	12.57	7.4	.688	3.48	--	1.6	2,700	1,300
4-26	11.87	4.8		2.03	4.0	2.4	1,300	50
4-27	9.83	31.0	.500	4.65	21.6	2.8	13,000	2,400
4-28	12.01	7.5	.368	2.05	8.0	5.2	34,800	1,090
				SLIGO CREEK - CHILLUM MANOR				
4-24	12.07	4.5	.388	5.30	8.8	4.0	> 160,900	160,900
4-25	13.32	6.8	.732	4.86	3.2	.4	>1,609,000	>1,609,000
4-26	12.86	4.5		3.25	2.0	2.0	130,000	50,000
4-27	9.97	27.0	.535	5.96	19.6	3.2	230,000	58,000
4-28	9.89	7.6	.545	4.15	10.4	6.4	3,480,000	290,000
				BLADENSBURG MARINA				
4-24	6.05	26.0	.288	4.60	13.2	2.4	34,800	9,180
4-25	7.61	39.0	.258	3.75	44.4	4.8	46,000	17,000
4-26	7.16	35.0		3.93	38.8	6.4	24,000	200
4-27	8.10	49.0	.523	8.77	30.0	5.0	210,000	63,000
4-28	9.89	26.0	.291	3.20	25.6	9.6	32,000	7,000
				US 50 BRIDGE				
4-24	5.31	57.0	.525	6.68	73.2	12.4	5,420	130
4-25	6.72	74.0	.537	5.08	103.6	15.2	13,000	1,700
4-26	4.23	56.0		5.13	66.8	12.8	1,300	330
4-27	5.83	150.0	.198	6.23	103.2	18.0	13,000	5,420
4-28	9.45	42.0	.265	4.59	82.0	18.0	24,000	3,480
				NORTHEAST BRANCH - RIVERDALE				
4-17	10.65	23.0	.252	3.38	22.0	5.2	22,100	1,090
4-18	10.51	34.0		4.19	35.0	4.0	4,900	1,720
4-19	10.95	25.0		2.89	26.0	10.0	7,000	1,300
4-20	11.64	23.0	ND	3.52	21.0	13.0	2,300	800
4-21	11.22	27.0		4.33	18.0	3.0	1,300	220

ND - Not detectable

Date Sample Taken	DO mg/l	Turb. JTU	LAS/ABS mg/l	BOD mg/l	Susp. Sol. mg/l	Vol. Sol. mg/l	Coliform MPN	Fecal Coliform MPN
				NORTHEAST BRANCH - RIVERDALE				
4-24	11.11	33.0		3.15	36.0	3.6	5,420	> 90
4-25	12.16	22.0		2.17	14.8	4.0	1,300	490
4-26	11.51	31.0		2.35	29.2	6.4	1,090	20
4-27	10.32	46.0		4.17	50.0	5.6	10,900	3,480
4-28	11.24	17.0		1.63	12.8	2.0	2,400	1,300
				NORTHWEST BRANCH - QUEENS CHAPEL RD.				
4-17	10.32	5.8	.252	6.09	21.2	8.8	700	70
4-18	11.22	17.5	.150	5.22	20.0	14.0	>160,900	91,800
4-19	11.68	11.0		8.87	5.0	3.0	34,800	16,090
4-20	12.17	5.6	.450	3.21	--	--	14,000	7,000
4-21	12.31	5.3		3.17	6.4	2.0	4,900	< 200
4-24	12.00	3.8		3.28	3.2	4.0	4,900	330
4-25	13.09	7.9		2.67	26.0	6.0	1,720	790
4-26	12.56	4.9		2.24	3.2	2.0	2,400	110
4-27	10.24	21.0		3.35	14.0	3.6	13,000	5,420
4-28	11.99	7.1		1.57	7.2	2.8	5,420	790

APPENDIX B

NUTRIENT CONCENTRATIONS
AT
BLADENSBURG BRIDGE ROAD
ANACOSTIA RIVER
1966

Sampling Date	River Flow (cfs)	NO_3 as N mg/l	Total PO_4 as PO_4 mg/l	TKN as N mg/l
1-13	15	1.306	0.240	
1-20	14	1.171	1.360	1.510
1-25	20	1.036	2.220	1.950
2-05	19	1.511	0.460	0.860
2-09	20	1.123	0.560	1.460
2-14	375	0.965	1.940	1.650
2-21	34	0.842	0.210	
2-28	358	1.149	0.190	
3-07	38	1.552	0.530	
3-07	38		0.500	
3-14	30	0.790	0.380	
3-16	25	0.723	0.370	
3-28	25	0.756	0.120	
3-30	22	0.832		
4-19	34	0.747	0.470	
4-26	52	0.512	0.470	1.421
5-02	147	0.540	0.560	1.047
5-09	38	0.453	0.630	1.242
5-16	27	3.074	0.540	0.847
5-23	28	0.381	1.230	1.309
6-06	21	0.590	0.190	1.148
6-13	15	1.429	0.390	1.046
6-20	14	0.351	0.340	
6-22	10	0.295	2.370	
7-05	45	0.702	0.410	1.000
7-13	8	0.340	0.090	1.630
9-08	1	1.050	0.480	0.630
9-16	557	1.200	0.830	0.390
9-22	115	0.600	0.320	
9-29	143	0.745	0.360	0.360
10-06	40	1.480	0.640	0.640

APPENDIX B (continued)

Sampling Date	River Flow (cfs)	NO_3 as N mg/l	Total PO_4 as PO_4 mg/l	TKN as N mg/l
10-13	30	2.570	0.580	1.010
10-20	559	0.450	2.210	4.220
10-27	50	0.590	0.730	0.860
11-03	84	0.400	0.980	0.920
11-10	77	0.420	4.270	3.100
11-18	56	0.900	0.130	0.320
12-01	56	0.840	0.480	0.750
12-08	46	0.550	0.480	0.300
12-15	147	0.990	0.500	0.660
12-22	85	0.960	0.570	0.490
12-29	155	1.690	0.540	0.780

APPENDIX C

ANACOSTIA RIVER
Kingman Lake
June 26-27, 1969
CHESAPEAKE TECHNICAL SUPPORT LABORATORY

Date Sample Taken	Time Sample Taken	Station Number	Water Depth Feet	Water Temp °C	Laboratory pH	DO mg/l	BOD mg/l	Coliform* MPN per 100 ml	Fecal Coliform* MPN per 100 ml
6-26	1150	A 1	2	29.5	6.40	2.75	7.44	93,000	93,000
	1340	2	2	29.2	6.38	4.16	7.18	93,000	24,000
	1335	3	-	29.2	6.22	2.41	5.28	43,000	24,000
	1330	4	-	29.3	6.30	2.38	5.68	43,000	24,000
	1320	5	-	29.5	6.25	1.44	4.14	43,000	15,000
	1307	6	10	29.5	6.42	2.24	4.80	93,000	24,000
	1257	7	10	30.0	6.40	1.91	6.34	240,000	4,300
	1247	8	10	29.8	6.30	1.35	4.46	93,000	4,300
	1234	9	6	29.9	6.30	2.14	4.86	43,000	24,000
	1208	10	4.5	30.0	6.30	1.88	5.28	43,000	43,000

Note: Sta A2: Oily smell, soft mucky bottom. No living organisms observed.
Sta A9: Sludge worms, oil odor, very soft bottom.

6-27	0937	A 1		30.5	6.15	1.91	9.28	93,000	24,000
	0920	2		30.0	6.20	2.56	9.12	43,000	2,300
	1115	3		28.5	6.33	2.75	10.44	24,000	9,300
	1107	4		28.5	6.40	2.20	9.74	43,000	7,300
	1100	5		29.5	6.42	2.20	7.98	15,000	2,300
	1051	6		28.5	6.41	2.53	9.78	15,000	2,100
	1043	7		29.5	6.42	2.04	7.88	43,000	4,300
	1024	8		30.0	6.52	1.98	7.90	43,000	3,900
	1017	9		31.5	6.53	1.69	7.28	24,000	2,100
	0951	10		31.5	6.53	1.84	7.70	93,000	15,000

* Analyses run by D. C. Blue Plains Waste Treatment Plant personnel.

C/

Station Description:

1	Intersection of stream and Anacostia, north of North Kingman Lake bridge.
2	Kingman Lake, north of northmost island.
3	Kingman Lake, northeast corner of third northmost island, first above bridge.
4	Kingman Lake, just north of Benning bridge.
5	Kingman Lake, west side of island, between stone outfall and drainpipe.
6	Kingman Lake, east side of southmost island.
7	Kingman Lake, just south of East Capitaol Street Bridge.
8	Kingman Lake, north of locks, east of hospital.
9	Anacostia River, south of locks.
10	Anacostia River, south of Benning bridge.